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Maintaining Fluid Systems

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Safety

Steam Systems

Wireless Data Collection

Stainless Steels and Corrosion

Packaging

Thermal Oxidizers

Access Intelligence

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Editor's Page

Supporting advanced manufacturing

Manufacturing is becoming more advanced as companies adopt new technologies to stay competitive and to help achieve newer sustainability goals. The Covid-19 pandemic and issues, such as supply-chain shortages, have accelerated this adoption, particularly of digitalization. The shift to advanced manufacturing has created a need for different skillsets in the workforce.

Advanced manufacturing refers to the use of innovative technologies applied to manufacturing. While the technologies vary in different manufacturing sectors, the majority of advances currently referred to are related to automation and digitalization — such as artificial intelligence, machine learning, virtual reality, additive manufacturing (3-D printing), robotics, advanced data analysis and more. Traditional engineering curricula give students very limited exposure to these topics.

Training and education

Universities, industry and government are all actively working to address the skills gap in manufacturing. Companies are investing in training to upskill their workforce, as well as investing in, and partnering with, educational institutions. A recent example is the donation of over $1 million in equipment and money from ConocoPhillips (www.conocophillips.com) to Prarie View A&M University (www.pvamu.edu) for engineering and business analytics education.

Arizona State University (ASU; www.asu.edu) opened a new school last year that collaborates with several industrial partners, and aims to build upon the university's existing engineering programs to meet the growing demands of advanced manufacturing. ASU's School of Manufacturing Systems and Networks announced last month that it has added a doctoral degree to its bachelor's and master's degrees in its new manufacturing engineering program.

Last year, the U.S. Dept. of Commerce's National Institute of Standards and Technology (NIST; www.nist.gov) awarded over $2 million to seven organizations to develop manufacturing technology roadmaps in order to strengthen advanced manufacturing in critical and emerging technologies.

And last month, Virginia Tech (www.vt.edu) received a U.S. Dept. of Defense (DoD) grant to purchase cutting-edge 3-D metal printing technology for education and research. The award will fund up to $800,000 for a computerized additive friction stir deposition (AFSD) machine.

The DoD also supports a free machine-tool training program called America's Cutting Edge (ACE) that is designed to create skilled machinists for precision manufacturing. The program is led by the Institute for Advanced Composites Manufacturing Innovation (IACMI; www.iacmi.org).

A recent report by the National Academies of Sciences, Engineering and Medicine (www.nationalacademies.org) examines the skills gap in manufacturing and focuses on how undergraduate education programs can better address the needs [*1*]. Among the recommendations offered for education programs, industry and government are: to incorporate manufacturing into every engineering undergraduate program; to strengthen collaboration between academia and industry; and to engage undergraduates in "hands-on" experiences in advanced manufacturing.

These are a few examples of the growing momentum to build a workforce with the skills needed for advanced manufacturing. ■

Dorothy Lozowski, Editorial Director

1.National Academies of Sciences, Engineering, and Medicine. 2022. Infusing Advanced Manufacturing in Undergraduate Engineering Education. Washington, DC: The National Academies Press. http://nap.edu/26773

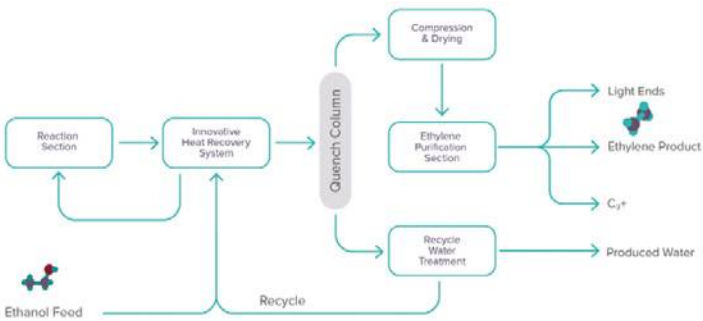
Scaleup for an ethanol-to-ethylene process

Last May, Axens (Rueil-Malmaison, France; www.axens.net) started up the first ethanol-to-ethylene pilot plant based on Axen's Atol technology with Sumitomo Chemical Co., Ltd. (Tokyo, Japan; www.sumitomo-chem.co.jp). The pilot plant, located at Sumitomo Chemical's Chiba Works, will produce ethylene from ethanol. The ethanol is produced from waste by Sekisui Chemical Co. Ltd. (Osaka, Japan; www.sekisuichemical.com) as part of the two Japanese companies' collaboration on circular-economy initiatives — and from bioethanol derived from biomass, such as sugarcane and corn.

In December 2017, Sekisui Chemical and LanzaTech Inc. (Skokie, Ill.; www.lanzatech.com) developed a process whereby waste is gasified into synthesis gas (syngas; CO + H_2), which is then converted into ethanol by a biofermentation process.

The Atol process was developed by Axens, IFP Energies Nouvelles (IFPEN; Rueil-Malmaison, France; www.ifpen.fr) and Total Refining & Chemicals (Brussels, Belgium; www.totalrefiningchemicals.com) (*Chem. Eng.*, May 2014, p. 11). In the Atol process (flowsheet), ethanol is dehydrated in the vapor phase at a temperature of 400–500°C and moderate pressure. The use of a heat diluent enables operation of the exothermic reaction using only two fixed-bed, adiabatic reactors in series. The patented thermal integration allows a maximized heat recovery, and therefore mimimized utilities consumption, says Axens. The very high selectivity of the Atol ethanol-dehydration catalyst leads to the recovery of polymer-grade bioethylene.

In addition to this first pilot plant, Axens says there are four additional Atol references currently under design.



Axens

In addition to validating the ethanol-to-ethylene technology, Sumitomo Chemicals will work to validate the ethanol-to-ethylene technology, and develop and produce polyolefin products from the renewable-ethanol-based ethylene, with the aim to commercialize production in fiscal year 2025.

A colorful new way to visualize gaseous properties

Japan's National Institute for Materials Science (NIMS; Ibaraki, Japan; www.nims.go.jp), along with Harvard University (Cambridge, Mass.; www.harvard.edu) and the University of Connecticut (Storrs, Conn.; www.uconn.edu), have designed a new imaging device that uses structural colors — visible colors that change based on the physical structure of a material — to visually discern the properties of different gases. Typical gas-imaging devices are complex, often requiring multistep measurements of pressure and strain, and may depend on infrared cameras or the injection of tracer particles. Often, these methods are not capable of producing images that enable robust analysis of gas characteristics, according to NIMS.

The new gas-imaging device is constructed of soft polydimethylsiloxane (PDMS), which is treated with argon and oxygen plasmas. Plasma-side down, the slab is then placed onto a glass substrate. By treating part of the slab with argon and part with oxygen, the PDMS will not fully bond to the glass, forming a specific boundary between the argon-treated areas and the glass, through which gases can flow. When compressed by the injection of a gas sample, a ripple-like deformation effect occurs at this interface. The compression and deformation of the PDMS, and the resulting pattern of ripples, produce structural colors that impact the device's optical transmittance. The key to this chemistry is maximizing the deformation so it can be used for measuring and visualizing the structural colors in the ripple patterns. As the PDMS deformation depends on gas flowrates, densities and viscosities, the produced structural colors can be used to analyze the properties of gas samples. According to NIMS, the team is investigating incorporating this technology into image-recognition and machine-learning techniques to improve gas analysis.

Edited by:
Gerald Ondrey

MAGNET METALS

Bilfinger SE (Mannheim, Germany; www.bilfinger.com) is supporting REEtec AS (Oslo, Norway; www.reetec.no) with engineering, procurement, construction and management (EPCM) services for a new processing plant for neodymium and praseodymium — two rare earth elements (REE) used in the permanent magnets of motors for electric vehicles (EVs) and wind turbines.

As with the demonstration plant, which has been in operation at Herøya Industrial Park since 2019, Bilfinger subsidiary Bilfinger Nordics is handling the EPCM services. Once completed, the REEtec plant on Herøya will have a capacity of 720 tons of magnetic metals per year from the second half of 2024. The Herøya plant will process rare-earth carbonates produced by Vital Metals in Canada. A second plant is planned to be built in Herøya in 2026.

REEtec's proprietary technology can reduce CO_2 emissions by 90% compared to other leading suppliers, as virtually all consumables are recovered and re-utilized in the process and electricity consumption is based fully on hydroelectric sources.

METALS FROM LIBs

Green Science Alliance Co., Ltd. (Kawanishi, Japan; www. www.gsalliance.co.jp) has developed a deep eutectic solvent (DES) that can be used to extract metals, such as cobalt, nickel and manganese, from cathode materials and waste (black mass) of lithium-ion batteries (LIBs). The natural DES is said to be safer and more environmentally friendly than the inorganic

(Continues on p. 6)

acids and solvents currently used for recycling LIBs.

DES is a solvent that has characteristics that are similar to ionic liquids, but is less expensive. Composed of Lewis or Brønsted acids, and basic materials, the mixture has a lower melting point than that of any individual component's melting point.

A LOAD OF REEs

Following successful exploration, LKAB Koncernkontor (KLAB; Luleå, Sweden; www.lkab.com) reported last month that it has identified mineral resources of rare earth metals exceeding 1 million metric tons of rare earth oxides and the largest known deposit of its kind in Europe. The Per Geijer deposit is in close proximity to existing mining operations in Kiruna. More extensive studies show an increase from 400 million m.t. of mineral resources with high iron content to over 500 million m.t., and that the Per Geijer deposit contains up to seven times the grade of phosphorus as the orebodies that LKAB mines in Kiruna today.

"This is the largest known deposit of rare earth elements in our part of the world, and it could become a significant building block for producing the critical raw materials that are absolutely crucial to enable the green transition," says Jan Moström, president and Group CEO, LKAB.

LKAB plans to submit an application for an exploitation concession in 2023. "If we look at how other permit processes have worked within our industry, it will be at least 10–15 years before we can actually begin mining and deliver raw materials to the market," says Moström.

CO_2 TO CARBON

At the end of last year, a new test facility started up at the Karlsruhe Institute of Technology (Germany, www.kit.edu) as a first phase of the €1.5-million research project NECOC (NEgative CarbOn Dioxide to Carbon). The facility is able to process

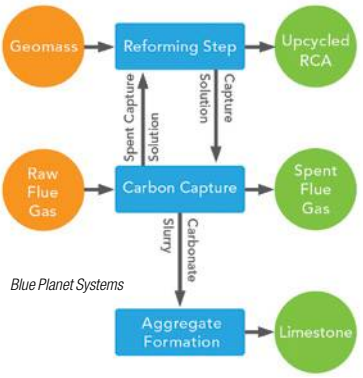
(Continues on p. 8)

Carbon sequestration in synthetic constuction aggregate

Blue Planet Systems (Los Gatos, Calif.; www.blueplanetsystems.com) and Sulzer Chemtech Ltd. (Winterthur, Switzerland; www.sulzer.com) have announced a partnership to accelerate development of Blue Planet's process for mineralizing carbon dioxide gas into construction aggregate for concrete. By sequestering CO_2 into the aggregate, the process can offset the carbon footprint of traditional cement and generate carbon-negative concrete.

"Most of the carbon dioxide on the planet is contained in limestone [calcium carbonate; $CaCO_3$]," explains Kyle Self, VP of engineering at Blue Planet. "Our process is meant to mimic the natural conversion of CO_2 into $CaCO_3$ and permanently store CO_2 in the built environment."

To achieve CO_2 sequestration, the Blue Planet process involves three primary steps. The process gets its alkalinity and calcium, needed for CO_2 capture and $CaCO_3$ mineralization, respectively, from a step that uses an acidic aqueous solution to extract the alkalinity and calcium from a variety of "geomass" materials, ranging from waste concrete to many rock types. The resulting alkaline aqueous solution, which is also made up of calcium ions, is then combined with CO_2-containing exhaust gas in a second process step, to absorb CO_2 upon contact and subsequently precipitate solid $CaCO_3$ (Figure) The third process step then isolates and converts solid $CaCO_3$ into synthetic sand and gravel, suitable for use as construction aggregate in concrete, wherein the captured CO_2 is permanently sequestered.



The "geomass" used in the initial step gets upcycled in the process and so yields a byproduct that is also suitable for use in the built environment.

Self says the technology does not require catalysts or specialized equipment. Rather, it works with standard chemical processing equipment configured in a specific way and re-purposed for the mineralization process. Blue Planet and Sulzer engineers have collaborated to achieve an absorption process with high surface area for mass transfer, but also with a low pressure drop.

Blue Planet says the process permanently mineralizes 440 kg of CO_2 in each ton of synthetic construction aggregate produced.

The Blue Planet process is currently being demonstrated at a development facility in Pittsburg, Calif., where plans are also in place to construct a larger, production facility.

Capture ammonia reversibly with this new MOF

Production of ammonia by the Haber-Bosch process not only requires a lot of energy for the high-temperature (300–500°C) synthesis of NH_3 itself, but the recovery of ammonia takes place by condensation at –20°C. As a result, large changes in both temperature and pressure are required. Alternative methods for NH_3 separation could open the door to alternative processes operating under less extreme conditions.

To address this problem, chemists at the University of California, Berkeley have designed and synthesized porous metal-organic frameworks (MOFs) that selectively bind and release NH_3 at modest pressure and temperatures around 175°C. As a result, less energy is required for the smaller temperature swings.

The study, published last month in *Nature*, involves a relatively new variety of MOF that has copper atoms linked by cyclohexanedicarboxylate molecules. In the presence of NH_3, this rigid, highly porous MOF structure is converted into strands of copper- and ammonia-containing polymer that has a high density of stored ammonia. The captured NH_3 can be released at relatively low temperatures, and the MOF returns to its original structure. Alternative MOFs that have been tried in the past are typically destroyed by the corrosive gas, and other porous materials, such as zeolites, have a low adsorption capacity for NH_3.

The study showed that exposure of the MOF to NH_3 caused the structure to change from a porous, 3-D material into 1-D strands. When the NH_3 is released, these strands weave themselves back into the original 3-D framework.

The researchers report that the new MOFs can be "rationally tuned" to match the reaction conditions of a specific application. The threshold pressure for NH_3 adsorption can be tuned by almost five orders of magnitude, the scientists report.

2 kg of CO_2 — from air — into 0.5 kg of carbon. The start of the test installation is an important milestone for the NECOC project, as well as the end of the first funding phase. In a second phase, the NECOC process will be optimized to be more energy efficient, and then scaled up.

The NECOC process combines three steps: First, CO_2 is adsorbed from air by direct air capture. Second, the CO_2 is converted to methane by a methanation reaction performed in a microstructured reactor using H_2 from an electrolyzer. Byproduct water is returned to the electrolyzer, and the CH_4 fed to a third reactor, where it is pyrolyzed as it bubbles through molten tin into carbon and H_2. The H_2 is returned to the methanation reactor, and the carbon mechanically removed as it floats on the tin. Depending on the process temperature, different carbon modifications (graphite, carbon black or even graphene) can be produced.

The NECOC project is coordinated by Benjamin Dietrich of the KIT Institute of Thermal Process Engineering (TVT), with funding from the German Federal Ministry for Economics and Climate Action. Partners in the project are Karlsruhe Liquid Metal Laboratory (KALLA) as part of the Institute for Thermal Energy Technology and Safety (ITES), as well as the Institute of Thermal Process Engineering (TVT). Project partners are Ineratec GmbH (a KIT spinoff), and Climeworks Deutschland GmbH.

RECYCLING TEXTILES

Anellotech, Inc. (Pearl River, N.Y.; www.anellotech.com) plans to begin advanced laboratory testing and scale-up for its Tex-TCat process for recycling textile waste. Tex-TCat is a fluidized-bed catalytic pyrolysis technology that is said to be the first process that efficiently recycles mixed waste textiles directly into the same chemical feedstocks (including benzene, toluene and xylenes; BTX) that are used today to make virgin synthetics like polyester and nylon. This provides a closed-loop, fiber-to-fiber alternative to incineration or forming intermediates, such as pyrolysis oil.

(Continues on p. 9)

A more stable way to upcycle waste plastics

A new advanced recycling process simplifies the task of breaking down polymer chains and stabilizing the resulting fragments. The Hydrochemolytic technology (HCT), developed by Aduro Clean Technologies, Inc. (Sarnia, Ont., Canada; www.adurocleantech.com), involves processing waste plastic with water, an inexpensive catalyst, and material the company refers to as the "H-source." In contrast with thermolytic approaches, such as pyrolysis and hydrothermal liquefaction (HTL), HCT relies on chemical mechanisms operating at sub-cracking temperatures to deconstruct the long carbon backbone of polymers in plastics, such as polyethylene, polypropylene and polystyrene. "It's a random process that generates progressively shorter molecular fragments to yield a mixture of lighter hydrocarbons," explains Gene Cammack, chief operating officer at Aduro. Further differentiating HCT is the "H-Source," which generates a form of hydrogen that quenches reactive intermediates formed as the polymer chain is cut.

Thermolytic methods also break down polymers to generate molecular fragments, but they do so by cracking at much higher temperatures. "Consequently, uncontrolled side reactions ensue that generate dozens and hundreds of different compounds with diverse chemical functionalities. These include high levels of unsaturated olefin compounds," says Cammack, "which are unstable and require mitigation through downstream hydrotreating."

By constrast, the selective operation of HCT to cut the polymer chains, and doing so at lower temperatures, not only reduces energy use but also minimizes uncontrolled side reactions. And the stabilization further limits side reactions while substantially eliminating olefins. Additionally, says Cammack, the process can be configured to tune the weight of the hydrocarbon products for certain product slates, such as naphtha, paraffins and other platform chemicals.

Having demonstrated HCT through extensive runs in batch reactors, Aduro is now implementing it in continuous-flow mode. Company scientists also are actively working to understand and manage the effects of contaminants in waste plastic streams, like PVC, and investigating possibilities to recover and reuse water.

Hydrothermal synthesis of cobalt-free lithium-ion-battery cathodes

Researchers at the U.S. Department of Energy's (DOE; Washington, D.C.; www.energy.gov) Oak Ridge National Laboratory (ORNL; Oak Ridge, Tenn.; www.ornl.gov) have developed a hydrothermal-synthesis method for high-voltage lithium-ion battery cathodes that avoids several key issues with traditional battery processing. Key among these issues is the reliance on cathode chemistries containing cobalt, a relatively rare and expensive metal that can cause health problems for miners and is generally mined in regions outside the U.S. Aside from the use of cobalt, cathode production often requires potentially hazardous chemicals, such as ammonia, and uses large amounts of water.

ORNL researchers, led by principal investigator Ilias Belharouak reported, in the *Journal of Power Sources*, a cleaner, less-expensive, more-efficient method for making a new class of high-capacity cathode material without cobalt. Instead of continuously stirring cathode materials with chemicals in a reactor, their hydrothermal-synthesis approach crystallizes the cathode using metals dissolved in ethanol, ORNL says. The ethanol is safer to store and handle than ammonia (used in the traditional process), and can be distilled and reused.

The patent-pending hydrothermal synthesis method is also much faster, notes ORNL lead researcher Rachid Essehli. The time required to make particles and prepare for the next cathode batch drops from as many as a few days to 12 hours.

In addition, the material produced has more uniform, round, tightly packed particles that are ideal for a cathode, Essehli says. Although the ORNL team has previously identified other cobalt-free combinations that work, the material discussed in this research was better at maintaining stability throughout the battery charge cycle.

Because the cathode properties are similar to those of today's cobalt-based cathodes, the new material can be seamlessly integrated into existing battery manufacturing processes, and is ready to be scaled up for commercial production by industrial partners, according to ORNL.

Harvesting hydrogen from humid air

Chemical engineers from the Swiss Federal Institute of Technology Lausanne (EPFL; www.epfl.ch), in collaboration with scientists from Toyota Motor Europe (Zaventem, Belgium; www.toyota-europe.com), have invented a photoelectrochemical (PEC) "artificial leaf" that splits water vapor into H_2. The technology features a gas-diffusion electrode that has three essential properties: It is transparent, enabling light to pass through; it is porous, enabling the transport of both reactant and product gases; and it is electrically conductive, enabling electron-transfer to occur. Up to now, most PECs, which couple semiconductor-based solar-proton harvesting with electrochemical transformations, require liquid-based electrolytes that are typically corrosive strong acids or bases.

Inspired by polymer-electrolyte membrane (PEM) flow cells, which use a solid electrolyte membrane and gas-phase input and output, the scientists developed a gas-phase PEM-PEC device. Key to the innovation is the optical transparency of the porous-conductive substrate. Most gas-diffusion electrodes are made out of carbon cloth or metal mesh or felt, which limits the harvesting of light and prevents transmittance of photons to the photoelectrode, the researchers report in a recent issue of *Advanced Materials*.

To address this drawback, a substrate was made from commercially available fused quartz fibers (SiO_2 wool). The fibrous material was processed into an interconnected felt by sintering at 1,350°C, which fused the interconnections into a rigid, transparent porous substrate (TPS). This was then made electrically conductive by coating with fluorine-doped tin oxide (FTO) via atmospheric chemical-vapor deposition. The wafer was then coated with a thin-film of sunlight-absorbing semiconductor materials. Finally, a cell was constructed using the coated wafer and a membrane for separating the H_2 product. This proof-of-concept prototype, based on the materials used, has a modest maximum theoretical solar-to-hydrogen conversion efficiency of the coated wafer of 12%, compared to 19% demonstrated for liquid cells. Now, the researchers are focusing their efforts on optimizing the system, as part of the E.U. Sun-to-X project (www.sun-to-x.eu).

Quantum-based tool searches quadrillions of materials to optimize catalysts

For the first time, a quantum-computing-inspired tool has been used for catalyst discovery — specifically for the investigation of a new catalyst for the production of hydrogen via electrolysis. Created jointly by scientists from Fujitsu Ltd. (Tokyo; www.fujitsu.com) and the University of Toronto (www.utoronto.ca), the Digital Annealer platform is designed to solve combinatorial optimization problems that require determining an optimized configuration from a large set of possible options. "In our project, we used it to identify catalysts with optimal properties for green-hydrogen production. It works by encoding the problem into a set of binary variables and using quantum-inspired algorithms to search for the optimal solution," explains researcher Jehad Abed.

To evaluate potential catalyst candidates, the Digital Annealer can look at many properties, including catalytic activity selectivity and stability. "Our goal was to identify catalysts that are not immediately apparent using traditional methods, such as heuristic searches or other machine-learning approaches," adds Abed. Using the "cluster expansion" technique, the team estimated that they used the Digital Annealer to analyze potential catalyst-material designs in the range of hundreds of quadrillions. This analysis led them to a potential catalyst-material family that is believed to be previously unexplored, comprising ruthenium, chromium, manganese, antimony and oxygen. The team synthesized samples of the discovered compounds and found that one of the candidates demonstrated a mass activity around eight times higher than other electrolysis catalysts, and also showed promising operation in acidic conditions.

The team is planning to expand the tool's breadth for various catalyst applications "We have open-sourced the code to enable wider adoption of our method. With the introduction of newer computing architecture, paradigms and search algorithms, we believe this approach can prove to be a useful tool to compare catalyst efficiencies and accelerate materials discovery," says University of Toronto researcher Hitarth Choubisa. ■

Laboratory-scale studies have demonstrated that Tex-TCat can process a variety of common textile materials that are incinerated or landfilled today — including cotton, polyester, nylon, elastane, acrylic and polyurethane, as well as blends of these and other commonly used textile materials.

The next steps include optimizing the feedstock preparation for efficient reactor feeding, as well as additional laboratory studies that will lead to long-term trials in Anellotech's 500-kg process demonstration plant. The company is currently seeking partners to accelerate the development and commercialization of the technology. The vision is to operate at scale with the first plant able to process about 200,000 metric tons (m.t.) per year, and subsequent plants as large as 1 million m.t./yr, depending on feedstock availability.

SHAPE MATTERS

Cube-shaped cobalt oxide nanoparticles are more efficient electrocatalysts for water splitting than spherical ones. This is the conclusion of a recent study, published in *Advanced Functional Materials*, by the group of professor Kristina Tschulik at Ruhr University Bochum (Germany; www.rub.de), in collaboration with researchers from the University of Duisburg-Essen (Duisburg, Germany; www.uni-due.de).

The researchers developed a way to directly analyze individual particles in solution. This enables them to compare the activity of different nanomaterials with each other in order to understand the influence of particle properties (shape and composition) on water splitting. The Bochum group's experimental findings were confirmed by theoretical calculations (using density-functional theory) performed by its cooperation partners headed by professor Rossitza Pentcheva at the University of Duisburg-Essen. The latter's theoretical analyses indicate a change in the active catalyst regions (Co atoms), which are surrounded by oxygen atoms forming an octahedron, to Co atoms that are surrounded by a tetrahedron. ❐

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Plant Watch

Entegris to expand production capacity of Electronic Chemicals facilities

January 12, 2023 — Entegris, Inc. (Billerica, Mass.; www.entegris.com) plans to increase production and purification capacity for its Pueblo, Colo. and Hollister, Calif. sites to support the anticipated increase in demand for its Electronic Chemicals business. The Electronic Chemicals business is part of Entegris' Advanced Planarization Solutions division and includes ultra-high-purity acids, bases, solvents and formulated blend chemistries for use by semiconductor manufacturers.

Chemours to expand production of ion-exchange materials in France

January 12, 2023 — The Chemours Co. (Wilmington, Del.; www.chemours.com) announced a $200-million investment to increase capacity and advance technology for its Nafion ion-exchange materials at the company's manufacturing facility in Villers-Saint-Paul, France. The project will include the expansion of ionomer production and associated membranes to deliver additional capacity in the Nafion materials supply chain to support growing market demand for clean-hydrogen generation using water electrolyzers.

LG Chem plans to produce plastics from marine-waste materials

January 12, 2023 — LG Chem (Seoul, South Korea; www.lgchem.com) is partnering NETSPA in building a resource-circulation system for recycling marine wastes. Through this agreement, LG Chem will secure raw materials for its pyrolysis-oil plant in Dangjin, South Korea, which is scheduled to begin operations in 2024. Once NETSPA sorts and processes plastics from marine wastes, such as discarded fishing nets, LG Chem will use it to produce recycled plastics.

BASF breaks ground on MDI capacity expansion project at Geismar site

January 11, 2023 — BASF SE (Ludwigshafen, Germany; www.basf.com) has broken ground on the third and final phase of the methylene diphenyl diisocyanate (MDI) expansion project at its *Verbund* site in Geismar, La. The company will increase production capacity to approximately 600,000 metric tons per year (m.t./yr). The investment for this final expansion phase, which takes place from 2022 to 2025, amounts to $780 million.

Raven SR, Chevron and Hyzon to produce hydrogen from waste in California

January 10, 2023 — Chevron Corp. (San Ramon, Calif.; www.chevron.com) is collaborating with Raven SR and Hyzon Motors to commercialize operations of a green waste-to-hydrogen production facility located in Richmond, Calif. Raven SR will be the operator of the facility, which is targeted to come online in the first quarter of 2024. The project is expected to divert up to 99 m.t./d of landfill waste into the plant's non-combustion reforming process, producing up to 2,400 m.t./yr of renewable hydrogen.

SK Geo Centric and Plastic Energy building world-scale recycling plant

January 11, 2023 — SK Geo Centric (Seoul, South Korea; eng.skgeocentric.com) and Plastic Energy (London, U.K.; www.plasticenergy.com) plan to build a pyrolysis plant in the Ulsan plastic-recycling complex. SK Geo Centric will start construction on the plant this year, which is anticipated to have a processing capacity of 66,000 m.t./yr of end-of-life plastic waste input, the largest capacity in Asia.

Sumitomo Chemical completes pilot facility for acrylic-resin recycling

January 3, 2023 — Sumitomo Chemical Co. (Tokyo, Japan; www.sumitomo-chem.co.jp) constructed a new pilot facility for the chemical recycling of acrylic resin (polymethyl methacrylate) in Niihama City, Japan. With Japan Steel Works, Ltd., Sumitomo Chemical has jointly developed a technology for pyrolyzing acrylic resin and recycling it into methyl methacrylate (MMA) monomer, a raw material for acrylic resin.

Black & Veatch to deliver desalination plant to major copper smelter in Indonesia

January 3, 2023 — Black & Veatch (Overland Park, Kan.; www.bv.com) will design and manage the delivery of a seawater desalination plant for PT Freeport Indonesia's Manyar Smelter in East Java. The desalination plant will produce over 1,400 m^3/h of desalinated seawater to support the copper smelter and precious-metals refinery. Designed to process 1.7 million m.t./yr of copper concentrate, the $3-billion Manyar Smelter is anticipated to be the world's largest designed single-line copper-processing facility.

Mergers & Acquisitions

ExxonMobil to divest its interest in Esso Thailand

January 12, 2023 — ExxonMobil Corp. (Houston; www.exxonmobil.com) reached an agreement with Bangchak Corp. to sell its interest in Esso Thailand, including the Sriracha petroleum refinery and select distribution terminals. The transaction will be executed by ExxonMobil's affiliate, ExxonMobil Asia Holdings Pte. Ltd, which holds 65.99% interest in Esso Thailand. The transaction is expected to close in the second half of 2023.

Borealis acquires majority stake in recycling technology firm Renasci
January 12, 2023 — Borealis AG (Vienna, Austria; www.borealisgroup.com) has acquired a majority stake in Renasci N.V., a Belgium-based provider of recycling solutions. The acquisition will support Borealis by providing increasing long-term access to chemically recycled feedstock from Renasci's processing facility in Ostend, Belgium.

Lukoil sells petrochemicals and refining business in Italy
January 10, 2023 — PJSC Lukoil (Moscow, Russia; www.lukoil.com) announced that its subsidiary Litasco S.A. reached an agreement to sell the ISAB S.r.L. business to G.O.I. Energy. ISAB owns a petrochemical complex in Italy with petroleum refining, gasification and electricity-cogeneration plants.

Phillips 66 increases stakeholding interest in DCP Midstream
January 9, 2023 — The Phillips 66 Co. (Houston; www.phillips66.com) agreed to acquire all of the publicly held common units representing limited partner interests in DCP Midstream for an approximately $3.8 billion cash consideration. Phillips 66 expects to capture synergies of at least $300 million by integrating DCP Midstream into its existing midstream business.

Linde acquires U.S.-based gas distributor nexAir
January 6, 2023 — Linde plc (Guildford, U.K.; www.linde.com) has acquired the remaining interests in nexAir, LLC, one of the largest independent packaged-gas distributors in the U.S., with 2022 sales of approximately $400 million. Linde's wholly owned subsidiary Linde Gas & Equipment Inc. (LG&E) has held a minority interest in nexAir since 2012. LG&E has now purchased the remaining 77.2%.

Braskem bolsters 3D-printing portfolio with acquisition
January 4, 2023 — Braskem S.A. (São Paulo, Brazil; www.braskem.com.br) acquired taulman3D, a supplier of filaments for 3D printing, including nylon, polyethylene terephthalate (PET), recycled PET and more. The acquisition complements Braskem's existing portfolio of filaments, which includes polyethylene, polypropylene, carbon fiber, glass fiber and recycled polymers for 3D-printing applications.

Prayon finalizes acquisition of Febex business from Arkema
January 4, 2023 — Prayon S.A. (Engis, Belgium; www.prayon.com) completed the acquisition from Arkema S.A. (Colombes, France; www.arkema.com) of its shares in Febex. Febex produces electronic-grade phosphoric acid used in the manufacture of printed circuits and semiconductors.

Merck completes acquisition of Mecaro's chemicals business
January 3, 2023 — Merck KGaA (Darmstadt, Germany; www.merck.com) announced the closing of the transaction to acquire M Chemicals Inc., the company recently incorporated by Mecaro Co. Ltd. to operate its chemical business. With this acquisition, Merck gains several research and production sites in South Korea. ■

Mary Page Bailey

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Digital Tools Help Optimize Steam Systems

Measuring and monitoring tools simplify steam-system management and increase efficiency

Although widely used throughout the chemical process industries (CPI), steam systems are often neglected until there is an issue with safety, reliability or steam quality. However, as processors become more concerned with saving money on utilities and reducing CO_2 emissions, steam-system optimization is a growing trend, with more attention being paid to measuring, monitoring and managing steam systems and their components. Optimizing steam systems in this way not only reduces energy costs and emissions, but is likely to improve the availability and safety of the system, as well as quality of the steam.

"Chemical plants are very intensive steam users," says Patricia Provot, president of the Americas with Armstrong International (Three Rivers, Mich.; www.armstronginternational.com). "Steam may be used as a heat source to heat chemical components that go into chemical reactions. It may be used for heat tracing of viscous chemical components being transported or pumped from one vessel or location to another. It may be used in distillation columns, direct-injection strippers and spray drying applications. Steam is also frequently used in injectors to create a vacuum in a kettle or vessel and steam has a role in the creation of electricity at some chemical facilities."

Despite its importance, steam-system maintenance and management have traditionally been reactive with, at best, some preventative maintenance. "Most steam users don't really understand the impact a poorly maintained steam system has on their overall operation," says Tye Buckley, director of services with Spirax Sarco USA (Blythewood, S.C.; www.spiraxsarco.com). "Often, they are short-staffed and the priority is to get product out the door, so they are always in a reactive maintenance mode where they move from problem to problem, fixing them, with a focus of getting the system back online. But due to the current business climate, where they need to reduce costs, meet sustainability goals and still ensure capacity requirements, more processors are taking a strategic approach in which they make improvements to their steam system in order to increase reliability, safety and efficiency, while still meeting production targets."

FIGURE 1. Digital solutions provide data and information that help optimize steam systems for efficiency and reveal system issues before they cause a shutdown, increasing system reliability and productivity

Primarily driven by sustainability goals, this recent interest in optimizing steam systems is not without challenges, notes Buckley. "On top of having to increase production and manage costs, processors are now being challenged to improve their impact on the environment. Steam-system optimization focused on efficiency, productivity and reliability all while meeting sustainability goals, requires a balance and careful management," he says. "This is why digital solutions for steam-system measuring, monitoring and management are coming into play. They provide data and information that will not only help optimize steam systems for efficiency, but they also reveal issues before they become a shutdown situation, increasing system reliability and productivity" (Figure 1).

Steam-system optimization

"Many facilities deal with poor-quality steam or poor reliability of the system and they are often shocked when we perform a system assessment that points out how much money they are losing due to a poorly managed and maintained steam system," says Tucker Jackson, business systems manager with Steam Solutions (La Porte, Texas; www.steamsolutions.com).

Ron Bajon, director of engineering with Steam Solutions, adds: "While they may want an assessment for cost-reduction purposes or sustainability goals, what we often point out during the assessment is that steam systems tend to suffer a snowball effect. For instance, not only are they losing money and efficiency due to lack of maintenance and management of components like the steam traps, but if they aren't checking their steam traps and replacing those

Armstrong

FIGURE 2. SAGE UMT automatic steam-trap tester from Armstrong is an ultrasonic tool that can be used to take acoustical and temperature measurements at each steam trap and will immediately alert the tech to the condition of the steam trap and log the information to a mobile app

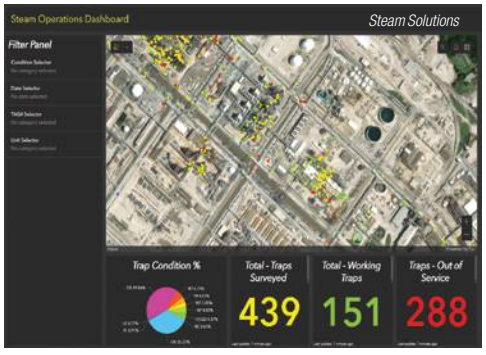


FIGURE 3. Steam Solutions' project management software tracks the GPS coordinates of each stream trap in an interactive map configuration that also displays the status of each trap

that have failed, the failed traps are likely to cause heat exchanger fouling or corrosion issues within the system, which can lead to system failure, poor-quality steam and water hammer, which can be a significant safety problem."

The good news is that the challenges associated with steam systems can be managed, says Chase Bean, director of engineering with Steam Management, Inc. (Boston, Mass.; www.steammgt.com). "There are over one hundred different types of opportunities to improve the efficiency and functionality of a steam system, and because improving one aspect of the steam system will often have a positive impact on the others [just as having one failed component will lead to system-wide issues], working to optimize the system can have many benefits for a facility," he says. "And with the recent attention on improving the efficiency of steam systems, more services and tools are becoming available to help operators optimize their systems with less effort than in the past."

Steam-trap optimization

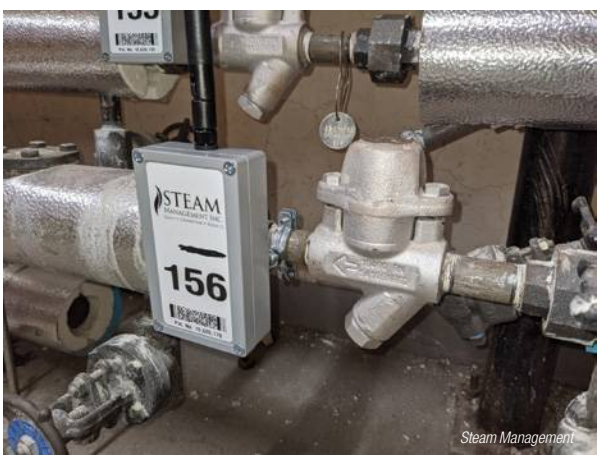
In addition to professional steam-system assessments and services, such as steam-trap maintenance and management programs, there are a variety of measuring and monitoring tools available to ease the burden of steam-system management and provide the data necessary to optimize the system in a way that improves both efficiency and functionality.

Because one of the biggest challenges in a steam system is condensate removal, which is directly related to steam-trap maintenance, steam-trap monitoring tools are a growing trend. "When it comes to steam traps, there can be issues with not having enough of them, as well as with keeping track of failures," explains Steam Solutions' Bajon. "Failed traps can have a huge impact on a steam system. If a trap fails open, they are just blowing steam straight out, which is not only wasting energy that you've paid to create, but it's also releasing CO_2 into the atmosphere, which is directly at odds with efficiency and sustainability goals.

"On the flip side, if the trap fails closed, it can create issues, such as reductions in heat transfer, which can lead to freezing in heat tracing applications, fouling of heat exchangers, which can create poor-quality steam and process issues, and water hammer, which builds up quickly and can knock pipes off their supports or blow out an elbow which requires major repairs and can be a concerning safety issue," says Bajon.

The problem with traditional steam-trap management is that there are hundreds to thousands of steam traps in most chemical facilities, so it's difficult to keep track of them. Manual assessments are time consuming, subject to operator error and are usually only performed once a year, even in a best-case scenario. Repairing steam traps that have failed is also labor intensive and time consuming and keeping track of it can be overwhelming in any size facility, according to the experts. As a matter of fact, according to Armstrong's Provot, about 20 to 25% of the steam traps are failed at any given time in many facilities. (For comparison, an optimized facility might have a 2 to 5% failure rate.) For this reason, some processors rely on professional steam experts to maintain and manage their steam traps, while others are embracing monitoring tools and technologies or implementing a combination of the two.

Currently, a new ultrasonic tool called the SAGE UMT automatic steam-trap tester (Figure 2) from Armstrong can be used to take acoustical and temperature measurements at each steam trap and will immediately alert the tech to the condition of the steam trap and log the information to a mobile application (app). "This makes surveying steam traps and reporting much more accurate and efficient because it removes the human element," says Steam Solutions' Jackson, who uses the technology when conducting assessments. The hand-held device can also be paired with Armstrong's SAGE Smart Utility System Management platform, which serves as an online database of steam traps. The information from the UMT survey can be directly uploaded to the software,



Steam Management

FIGURE 4. Continuous steam trap monitoring allows processors to manage their trap population easily while saving them energy and money and potentially preventing safety and process issues

which will then track and analyze the information so it can be used to create reports and maintenance workorders, and provide users with a dashboard so they can see which steam traps have been serviced, which ones are operating and which are chronic problems (which may point to an issue up- or downstream of the steam trap that needs to be addressed).

Steam Solutions also employs its own project-management software that tracks the GPS coordinates of each stream trap in an interactive map configuration that displays the status of each trap (Figure 3). "The software can be customized in many ways to suit each facility," says Bajon. "Additionally, any of the dots on map can be selected to display the information and a picture of that particular trap. We use this to show progress of trap surveys and it helps identify problem areas to simplify steam-trap management."

Continuous monitoring solutions are also available, says Steam Management's Bean, who offers Steam IQ (Figure 4) as an example. This system uses an ultrasonic probe that clamps onto the pipe downstream from the steam trap and continuously monitors the trap. Using algorithms, it can determine if the trap has failed. The information is processed and displayed on a web browser, which also provides information regarding replacement ordering information, plant location and the maintenance history of the steam trap. If the trap has failed, the dashboard will provide details about how much energy the trap is losing and how much money the loss is costing the facility. "Contin-

FIGURE 5. Rosemount vortex flowmeters help reduce downtime in steam applications by using a gasket-free meter body design to reduce leaks, along with non-wetted independent sensors that can be serviced without shutting down the process

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FIGURE 6. Endress+Hauser's FMP54 level transmitter with gas-phase compensation can be used in steam drums to prevent over and underfill, conditions that cause damage and safety hazards

uous monitoring in this way allows processors to manage their trap population easily while saving them a lot of energy and money and potentially preventing safety and process issues," says Bean.

Spirax Sarco's Buckley notes that digitalizing steam-trap management is extremely helpful for processors. "Solely collecting the data isn't enough," he says. "Without comprehension and action, data provides no value, so they must capture the data, process it, understand it and take necessary actions."

The ability to do this instantly and continuously using digital tools and solutions helps in many ways, he says. "First, we shift away from time spent finding the problem traps, to time spent fixing them. Second, when surveys are performed manually on an annual basis, it is entirely possible for a trap to be in a failed state for close to a year if it occurs soon after the annual survey. This means they can have many months of energy and sustainability losses or damage to the system that goes unnoticed," says Buckley. "So, by continuously monitoring steam traps and managing the information digitally, processors can avoid those losses and move to a more efficient, sustainable and functional system." Spirax Sarco helps processors achieve their sustainability targets through hardware, software and services to provide continuous monitoring and management for their steam systems.

In addition to the challenges associated with steam traps and condensate removal, steam efficiency is another significant issue, says David Wright, global DP flow product management engineer with Emerson (Shakopee, Minn.; www.emerson.com). "Depending on the type of steam, the energy required to maintain a specific temperature and pressure will constantly need to be adjusted," he explains. "Maintaining high-quality steam requires additional energy and supervision, which is difficult to provide without proper measurement. In addition, maintaining entire steam loops within the facility to ensure there are no leaks within the system can be a challenge with larger facilities and aging infrastructure."

The solution, he says, is using steam measurement, which helps to improve automation and leverage process equipment diagnostics. "Understanding the steam-system temperature, pressure and flow rates delivers insights into plant performance," says Wright. "Technicians can use this information to perform adjustments, increase efficiency and quickly pinpoint issues. Today's best practices and improvements in flow technologies can deliver reliable information, even in the most challenging installations."

To that end, Emerson offers multiple process-measurement solutions to completely monitor steam processes. These measurements include pressures, temperatures, flowrates, steam leaks and more. "With steam applications that measure flowrates, it's important to understand how much steam is running through the system. Using Emerson's Rosemount vortex flowmeters (Figure 5) or a Rosemount Annubar flowmeter allows plants to accurately measure these points in real time."

Both technologies offer multivariable configurations that provide real-time compensated mass flow, with integrated temperature and pressure compensation capabilities and the measurement technologies cover the full range of steam, from saturated to superheated to supercritical.

Other areas of concern, according to Kris Worfe, chemical industry manager with Endress+Hauser (Greenwood, Ind.; www.us.endress.com), include keeping steam at a consistent temperature to prevent re-heating and ensuring that condensate is returned to the system cleanly and efficiently to prevent heat exchangers and other equipment from corroding. "The water/condensate must be monitored and measured constantly for cleanliness because contaminants cause damage to systems. In addition, the flow of condensate and the flow of finished steam must be monitored with pressure and temperature measurements to help ensure quality," says Worfe.

In addition to tools that measure pressure, temperature and flow, as well as water-quality measurements including pH and conductivity, Endress+Hauser offers level monitoring instruments, such as the FMP54 level transmitter with gas-phase compensation (Figure 6), which can be used in steam drums to prevent over and underfill, conditions that cause damage and safety hazards.

The real-time information provided by these solutions allows technicians and engineers to perform preventive maintenance, make boiler adjustments and identify leakage, which provides improved performance and increases productivity and efficiency of steam systems, says Worfe.

Thanks to the digitalization of measurement, monitoring and management tools, it is easier than ever to optimize the functionality, safety and efficiency of steam systems. And, in today's climate of sustainability and doing more with fewer expenses, steam system optimization should be a priority. ■

Joy LePree

Focus on Packaging

SaaS integrates with packaging and labeling hardware

PalletWorks 2.0 tracking and labeling software (photo) is a subscription-based software as a service (SaaS) that integrates seamlessly into any manufacturing environment. Not only does it integrate with packaging and labeling hardware on the plant floor, but it also communicates with existing controls and enterprise-resource planning (ERP) systems. This complete integration makes PalletWorks suitable for increasing production accuracy and automating tasks at the end of the line. PalletWorks 2.0 includes everything required for an enterprise-level tracking and labeling solution. The software continuously monitors throughput, labels items and pallets, records production data, and can be seamlessly integrated with the ERP system for real-time updates. — *Cybertrol Engineering, Minneapolis, Minn.*

www.cybertrol.com

Print and inspect aluminium foils at a later stage

ChecKITprint (photo) is a hardware and software kit that can be installed on a blister machine or on a dedicated offline station, and allows: aluminium reel printing and inspection, even at high speeds of up to 75 m/min; homogeneous inspection of webs up to 367 mm with high resolution (600 dpi); and a wide range of materials to be supported. The benefits of late-stage customization include less warehouse storage space required; reduced costs for the purchase of different types of stock material; more flexibility to produce low- and medium-volume batches; and greater adaptability to regulatory changes. The product's software is integrated with yudoo, the industry 4.0 pharmaceutical software suite for the full management of automation processes, digital quality, data analysis, and track and trace. This digital hub is accessible from anywhere through a secure web interface or dedicated devices. — *SEA Vision Group, Pavia, Italy*

www.seavision-group.com

This continuous motion cartoner has a small footprint

The new PC 4201 continuous motion cartoner (photo) achieves a maximum output of 200 cartons per minute with a footprint no bigger than that of intermittent motion types. Thanks to its compact design and individual feeding systems, this efficient technology is suitable for connection to any primary packaging machine in the chemical, pharmaceutical, nutraceutical, food and cosmetic industries. Depending on the line configuration, pick-and-place systems ensure automated transfer of the products to the cartoner. To avoid producing empty packs, leading to unnecessary waste, the cartons are only picked up if there is actually any product waiting. The digitally adjustable format positions, which can be accessed on the human-machine interface (HMI), greatly simplify product changes. — *Romaco Group, Karlsruhe, Germany*

www.romaco.com

Dual-action detection and rejection machine

Both metal detection and weighing are vital to the packaging of products. Although there are machines that do one or the other, this company has incorporated the two into one unit, with one common interface, which resolves having separate machines with separate controls to perform required inspections. The Metal Detector Checkweigher Combo (photo) uses electromagnetic force restoration (EMFR) technology, instead of traditional strain gages used in other scales. This enables high repeatability and high part rates, leading to improved accuracy. Packages moving along a conveyor are first inspected for metal. If traces of metal are detected, the package is automatically rejected without slowing down the line. As pure packages continue along the conveyor, they are then checked for accurate weight. If it is either over or under the prescribed weight, then it is rejected into a different bin. — *Bunting-Newton, Newton, Kan.*

www.buntingmagnetics.com

Cybertrol Engineering

SEA Vision Group

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Bunting-Newton

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Schütz

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Dispense Works

Centrifugal sifter prepares dry materials for packaging

The GS Centrifugal Sifter (photo) automatically separates and conditions agglomerated powders, granules and other dry materials into fine powders ready for transfer to filling and packaging lines. Installed upstream of weigh filling, stick packaging, form-fill-seal, pouch packaging, bagging and other machinery, the sifter ensures the product stream meets the required specifications with a constant bulk density and a consistent, narrow particle-size distribution. Any oversized particles are automatically separated and returned upstream for further reprocessing or collected at discharge. The powder sifter features a proprietary rotating paddle assembly that directs fine particles through a mesh screen and diverts oversized particles at 99.9% efficiency. Offered in a choice of screen sizes and materials, the sifter yields consistent particle sizes from 40 µm to 5 mm as targeted at up to 120 ton/h. — *Gericke USA, Inc., Somerset, N.J.*
www.gerickegroup.com

QR code provides additional packaging information

The Info-ID (photo) is a QR code on the existing label on every intermediate bulk container (IBC) labeling plate. Users can scan the Info-ID with any internet-enabled mobile device to access a wide range of additional product information. Traceability and clear identification of packaging materials are essential features, particularly when transporting and storing chemicals, hazardous substances or sensitive goods, such as foods. Although the company already has a labelling system that makes it easy to identify the respective packaging material, the new Info-ID provides direct access to additional product-specific information that can be accessed by scanning a QR code. — *Schütz GmbH & Co. KGaA, Selters, Germany*
www.schuetz.net

Palletizing products in preparation for shipment

This company supplies its space-saving robotpac articulated robot to palletize products in special bags, drums, canisters, cartons and buckets. The unit loads are stacked precisely on pallets and can then be conveyed to the downstream packaging system, the company's stretch hood (photo). The stretch hood covers the palletized unit load with a highly elastic film, which protects the goods during handling and external storage, and against environmental influences such as ultraviolet (UV) radiation, dust and moisture. The stretch hood also has a modular design. With the support of data analytics, for example, large amounts of data can be collected on the machines and evaluated in a targeted manner, thus revealing potential for improvement. With the information gained, operations can be continuously improved. This has a positive effect on the lifecycle costs. — *Beumer Group GmbH & Co. KG, Beckum, Germany*
www.beumergroup.com

This filling and capping system is versatile

The Ring Dex 2 (photo) evolved from this company's standard line of filling and capping equipment. Each workstation is independent, servo-driven and features fully programmable motions for accommodating a variety of bottle sizes, capping pitch and torque, fill volumes, nozzle strokes and so on. Furthermore, this system can handle bottles with caps assembled on or caps supplied loose. Bottles are fed from bulk with the StepKing feeder, which provides gentle and quiet operation (no vibration), resulting in higher throughput with minimal part contact and scuffing. Furthermore, this method can handle a range of bottle diameters and lengths with no adjustments required. The system, along with the conveyors and tracks, is software-controlled, allowing users to easily create and edit menus using the intuitive HMI touchscreen controller. This file-based control system means hundreds of files or recipes may be stored on the machine's memory card. In most cases, changeover means just loading a new file. — *Dispense Works Inc., McHenry, Ill.*
www.dispenseworks.com

A packaging machine for blister packs

Integra 720V (photo, p. 20) is a robotized integrated line for packaging blisters in cartons. It can be equipped with the BL-A525 CW labeling machine and incorporate a checkweigher for dynamic weigh-

ing and control of cartons. What makes this line innovative is the inclusion of a new technology — a complete software package that aggregates the blister to the carton. This is a strategically important solution for all contexts where blisters are sold, distributed or separated from their original pack, whether by the end user or by other players along the distribution chain, such as in hospitals, or in pharmacies in many countries. The company also developed a predictive-maintence solution. Data from the sensors installed on the machine are collected, analyzed with the aid of artificial-intelligence algorithms, transformed into information useful to the operator and displayed by means of a dedicated web platform. — *Marchesini Group S.p.A., Pianoro, Italy*
www.marchesini.com

Fill powders into bags and seal them — hygienically

With the Adams technology (photo), powder products are filled into preformed bags made from a continuous tubular film. During filling, air is extracted from the bag with the aid of a vibrating lance and a compactor. Next, the packaging itself is hermetically sealed. The result: completely sealed and very compact bags. The filled bags are clean, weatherproof and safe, which are all required to meet high hygiene requirements. — *Haver & Boecker, Oelde, Germany*
www.haverboecker.com

A combined metal detector and checkweigher

The newest edition of this company's Raptor Checkweighing series is a compact, space-saving high-performance food metal detector and checkweighing combination machine. Targeting food waste and product giveaway, the Raptor Combination machine (photo) is

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simple to use, robust and hygienic. In addition to offering cost savings for end-users. The intuitive Raptor Combination machine captures and reports all the data required to guarantee food brand integrity and absolute traceability. Available in four standard belt widths (100, 200, 300 and 400 mm), the Raptor series for food processors operating in high-care sectors, including confectionery, chocolate, bakery, packaged meats and fish, cheeses, and ready-to-eat meals. — *Fortress Technology Ltd., Toronto, Ont., Canada*
www.fortresstechnology.com

These bag-discharge stations are versatile

Developed to promote the safe discharge and complete emptying of flexible intermediate bulk containers (FIBCs), super sacks and other bulk bags, these bulk-bag unloaders (photo) are custom-engineered with a wide range of design options and accessories to accommodate any powder processing application, including in hazardous, non-hazardous and sanitary environments. The line of bulk-bag unloaders can be configured for use with a forklift or with an automated chain hoist to ensure the filled bags are safely raised and held in place while a dust-tight iris valve assembly prevents any material from escaping into the workplace. Suitable for unloading bulk bags with up to 4,000 lb of powders, granules pellets and other dry, bulk materials, the rugged unloading stations are manufactured in stainless steel or mild steel with industrial or sanitary finish and continuous precision welds. Integrated bag breaking, bag conditioning, weighing and other equipment are also available as options.— *Automated Flexible Conveyor, Inc., Clifton, N.J.*
www.afcspiralfeeder.com

PE stretch films suitable for hazardous areas

Last year, DUO PLAST AG (Lauterbach, Germany; www.duoplast.ag) and this company introduced the world's first stretch polyethylene (PE) film approved for use in potentially explosive areas. The film innovation DUO EX-TRA is equipped with the static-dissipative polymer Elastostat. This creates the first stretch film suitable for use in potentially explosive atmospheres. The newly developed film avoids ignition source electrostatics, so stretched pallet units no longer pose an explosion hazard. Conventional stretch films are not approved for explosive areas due to the static charge, and pallets must be repacked before entering. The effort involved in unpacking or packing incoming and outgoing goods with conventional stretch film is enormous. Therefore, stretch films with Elastostat are particularly suitable for companies in the chemical process industries (CPI) and their suppliers, who can be supplied directly to hazardous areas in the future. — *BASF Polyurethanes GmbH, Lemförde, Germany*
www.basf.com

World's first PP flexible food packing uses 30% PCR plastic

In December, premium-brand instant noodle packaging made with 30% certified post-consumer recycled (PCR) plastic content launched in major retail outlets in Malaysia. This company collaborated with Scientex in the packaging value chain to enable the manufacturer to develop material for the world's first flexible food packaging based on advanced recycled ocean-bound plastic (OBP), using certified circular polypropylene (PP). The material is being used in packaging for a premium brand of noodles sold in Malaysia. The OBP used in the project is recovered and converted to pyrolysis oil in an advanced recycling process. This company uses this oil as an alternative feedstock to produce certified circular PP polymer for further processing to biaxially oriented polypropylene (BOPP) film. Scientex then manufactures and prints the noodle packs from this film. The entire chain from the management of the collected OBP to the final packaging is seamlessly accredited under established certification regimes. — *SABIC, Riyadh, Saudi Arabia*
www.sabic.com ■

Gerald Ondrey

Fortress Technology

Automated Flexible Conveyor

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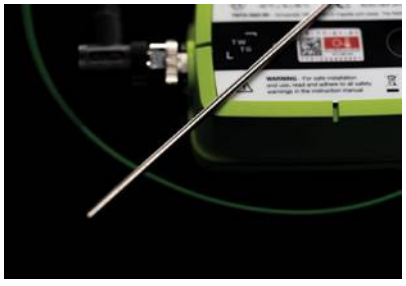
New Products

Graco



TWTG Group

DunAn Microstaq

TLV

A highly efficient electric double-diaphragm pump

Quantm is a new electric-operated double diaphragm pump (photo) that features an advanced electric-motor design that is said to be significantly more efficient than a standard pneumatic pump. The pumps' FluxCore motors and drives deliver up to eight times more continuous torque at low speeds than conventional motors, the company says. The pump offers a wide range of materials of construction to support multiple industrial and hygienic applications, including chemical processing, water treatment, paint manufacturing, pharmaceuticals and more. Designed to be a drop-in replacement for current pneumatic pumps or for greenfield construction, the pump is built for harsh industrial or hygienic environments, while also being lightweight and easy to maintain. — *Graco Inc., Minneapolis, Minn.*
www.graco.com

These temperature and vibration devices have new certifications

This company has recently received FCC, FM and IC certification for its NEON brand of temperature transmitters (photo) and vibration sensors. The NEON vibration sensor sends alerts to maintenance engineers as soon as assets, such as engines, conveyor belts and pumps, start to fail. This sets off a trigger when a change of amplitude is detected in the vibration spectrum or when outliers in the data occur. An engineer is alerted to check on this asset to prevent it from failure or long-term damage, which saves costs and ensures operational uptime. The NEON temperature transmitter is designed to be implemented quickly, and to transmit a signal for monitoring purposes via connection to an industrial thermocouple or RTD. The device can be connected to a thermocouple via an M12 connector with an up to 3-m-long extension cable. It uses onboard intelligence to determine average values over user-determined time scales to provide insights that can be used directly within existing systems. — *TWTG Group B.V., Capelle a/d Ijssel, the Netherlands*
www.twtg.io

A digital sensor that measures subcooling and superheating

This company's new digital pressure-temperature sensor (DPTS; photo) is designed to measure subcooling for HVAC-refrigeration applications. The DPTS is a self-contained device that measures pressure and temperature and calculates subcooling based on refrigerant type. It is compatible with safety-group A1, A2 and A2L refrigerants. The latest-generation DPTS can read maximum pressure between 500 and 700 psi. The DPTS is available as a superheat sensor as well. In a HVAC-R system, two DPTS sensors can be used to measure superheating and subcooling. Superheat measurements monitor the efficiency of the system and can be used as a safety sensor to protect the compressor from liquid flooding. Subcooling measurements monitor the refrigerant charge level and control the high-pressure flow-control valve to maintain the condenser mass flowrate. — *DunAn Microstaq, Inc., Austin, Tex.*
www.dmq-us.com

Get steam at its set pressure, nearly immediately

The MC-COS multi-control valve (photo) is a fully integrated device consisting of this company's COS pressure-reducing valve, a separator, steam trap and a motorized actuator. It is designed for steam conditioning, as well as to control either the steam pressure or temperature of steam-heated processes. A major benefit of the MC-COS is its ability to instantaneously supply steam at the set pressure — when the pressure set value is changed, the new target can be achieved quickly and accurately. The system's feedback-control configuration, as well as its servomotor-driven actuator with proprietary algorithms, contributes to fast response and avoidance of overshooting and undershooting. The system is appropriate for automated processes requiring that supplied steam be at a stable pressure, and processes with frequent fluctuations in the pressure setting, including corrugation machinery, dryers, presses and jacketed equipment. — *TLV Corp., Charlotte, N.C.*
www.tlv.com

These mass flow controllers have three new certifications

This company's SLA Series mass-flow controllers (MFCs; photo) and meters now have new global certifications, including those covering the cure dates and shelf life of the elastomers used in the assembly and the surface roughness of the flow path, as well as special certification for users in Japan. MFC instruments precisely measure and control the delivery of gases to production systems and chambers, such as bioreactors. Certain regulatory and safety requirements call for certification and documentation of calibration protocols or other declarations about the materials of construction in the "wetted path" of the MFC, where the process gas flows through the device. Devices of the SLA series feature a high turndown ratio, an extremely low-leak-rate valve, an enhanced sensor design and pre-calibrated multigas pages for air, carbon dioxide, nitrogen and oxygen. The SLAMf Biotech offering is specifically designed for bioprocessing and other life-sciences applications to enhance gas-flow control range, enable process recipe flexibility and satisfy regulatory compliance requirements. — *Brooks Instrument, Hatfield, Pa.*
www.brooksinstrument.com

New screw compressors with high capacity and low noise

The S-4 Series of screw compressors now includes options for the 45- to 75-kW performance range (photo). All models are characterized by quiet, reliable operation and have high efficiency. The compressors generate high free-air delivery at low specific-power consumption. The energy use of the new 75-kW compressor has been reduced by over 12% compared with its predecessor, while the free-air delivery has increased by almost 9%, according to the manufacturer. The new compressors come standard with low-energy IE4 motors and permanent-magnet motors. The compressors' vertical-oil separation concept ensures very low residual-oil content, minimal pressure losses and a long service life. The internal cartridge is easy to remove and replace. Maintenance takes place from two sides with just a few simple movements — the intake filter is accessible and both the oil and air coolers can easily be removed and cleaned. Furthermore, the company says it was able to reduce the noise in the 45-kW performance class by more than 8 dB(A). — *BOGE America, Inc., Powder Springs, Ga.*
www.boge.com/en

These pressure gages are now equipped for 400% overpressure

This company's 1209 solid-front stainless-steel pressure gage (photo) is now available with the new XRA option, which allows the gage to accommodate up to 400% overpressure without damaging the gage. In applications where pressure spikes, surges and waterhammer are a possibility, option XRA reduces the need for an external pressure-limiting valve while extending gage capacity. The 1209 is also available with optional liquid-fill or the patented PLUS Performance option to dampen shock, vibration and pulsation. The devices also come with IP65-rated weather protection, and are socket-welded for leak integrity. — *Ashcroft Inc., Stratford, Conn.*
www.ashcroft.com

Improve the connectivity of explosion-safety systems

Process equipment is usually connected by pipelines through which, if an explosion occurs, fire and pressure can spread very rapidly. Propagating explosions pose increased risks of secondary explosions. The intensity of the explosion in connected vessels is increased by pressure piling and flame jet ignition. In the event of an explosion detection by either infrared optical sensor or pressure-switch signals, the new EXKOP Express controller activates the connected explosion-isolation systems, such as this company's QV II or QV III quench valve (photo). Depending on the needs of a particular process, the EXKOP Express can also be used to activate the Q-Bic chemical-extinguishing barrier in one or multiple pipes. The Q-Bic system can protect large-diameter pipes, and the hygienic interface is compatible with sanitary food-processing installations. — *Rembe, Inc., Fort Mill, S.C.*
www.rembe.us ■

Mary Page Bailey

Brooks Instrument

BOGE America

Ashcroft Inc.

Rembe

Stainless Steels and Corrosion

Department Editor: Scott Jenkins

Stainless steels are common materials for process equipment and components in the chemical process industries in large part because of their corrosion resistance. This one-page reference reviews the properties of stainless steels with regard to corrosion resistance.

Passive layer

Stainless steels are not fundamentally inert materials, but rather, derive their corrosion resistance from a thin, invisible and insoluble layer of chromium and iron oxides and hydroxides, commonly called the passive layer (Figure 1).

Although the passive layer is only a few nanometers thick, it effectively keeps the metal beneath isolated from its surroundings, and electrochemical reactions causing corrosion are effectively slowed down. The passive layer reduces the corrosion rate to a fraction of what it would be without it.

The passive layer forms spontaneously in environments containing enough oxidants. If the metal beneath the passive layer is exposed by mechanical damage, it spontaneously repassivates. The oxygen content of air, and most aqueous solutions, is enough for both the creation and maintenance of the passive layer of stainless steels.

However, there are environments that cause permanent breakdown of the passive layer, allowing corrosion on the unprotected surface. For the passive layer to break down in its entirety, stainless steels need to be exposed under strongly reducing conditions. More commonly, the passive film is attacked locally, while the rest of the surface remains intact, causing various types of localized corrosion.

The situation that then occurs with an unfavorable anode-to-cathode area ratio can lead to rapid propagation once corrosion has initiated. Stainless steel is generally either passive or tends to corrode rapidly, in contrast to carbon steel, where gradual, uniform corrosion is expected.

Categories of stainless steel

Traditionally, stainless steels are categorized according to their microstructure into the following categories:

Ferritic stainless steels. Ferritic stainless steels, also known as chromium (Cr) steels, are alloyed with Cr, and sometimes a small amount of nickel (Ni). Molybdenum (Mo) is added to some steels to improve corrosion resistance, while alloying with niobium (Nb) and titanium (Ti) improves weldability. These steels have high resistance to stress corrosion cracking (SCC) but moderate resistance to uniform, pitting and crevice corrosion.

Austenitic stainless steels. Austenitic stainless steels are the largest group of stainless steels and have moderate to excellent corrosion resistance. This group can be divided into five subcategories:

- *Cr-Ni steels (18-8)*. These "general purpose" stainless steels are mainly alloyed with Cr and Ni but with no Mo. The "18–8" designation refers to their approximate Cr and Ni content. They have moderate resistance to uniform corrosion, as well as pitting and crevice corrosion, but rather poor resistance to SCC.
- *Cr-Mn steels (200-series)*. These steels are also referred to as "200-series" steels in reference to the AISI/ASTM nomenclature. Their Ni content is decreased and the austenitic microstructure is maintained by replacing some of the Ni with manganese (Mn) and nitrogen. They have moderate resistance to uniform, pitting and crevice corrosion, but rather poor resistance to SCC.
- *Cr-Ni-Mo steels*. Also "general purpose" stainless steels, this type is alloyed with Cr and Ni, but have increased corrosion resistance because of their Mo content. They are sometimes referred to as "acid-proof" stainless steels. They have good resistance to uniform, pitting and crevice corrosion, but rather poor resistance to SCC.
- *High-performance austenitic steels*. These steels were developed for use in highly demanding environments and contain high Cr, Ni and Mo content. Many steels of this type are also alloyed with nitrogen to further increase corrosion resistance and mechanical strength. Some of these steels are alloyed with copper to increase the resistance to certain acids. They have high resistance to uniform, pitting, crevice and SCC.
- *High-temperature austenitic steels.* These steels, developed for use at temperatures exceeding 550°C, have high Cr and Ni content, but also contain Mo. They have good oxidation and creep resistance.

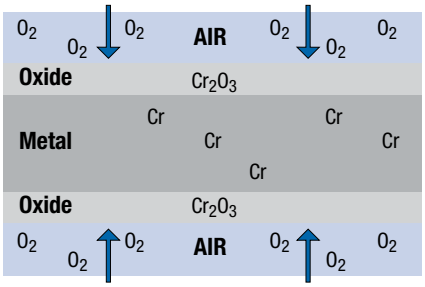


FIGURE 1. The passive layer of stainless steel is generated when oxygen from the air combines with chromium at the metal-air interface

Duplex stainless steels. Duplex stainless steels have a ferritic-austenitic microstructure, with a phase balance of approximately 50% ferrite and 50% austenite. Duplex steels combine many of the beneficial properties of ferritic and austenitic stainless steels. Compared with austenitics, they typically have high Cr content, but rather low amounts of Ni. Mo and nitrogen are incorporated to improve corrosion resistance and balance the microstructure. This group of steels has high resistance to SCC, while resistance to uniform, pitting and crevice corrosion varies between moderate and high, depending on the steel.

Martensitic and precipitation-hardening stainless steels. This type contains Cr without the addition of Ni and Mo (or sometimes only very tiny amounts). The corrosion resistance of these steels is generally lower than other stainless-steel families, and they are used mainly when high hardness is a key requirement. ■

Editor's note: This column is adapted from the following article: Signorelli, R. and Li, J. Materials of Construction: Stainless Steel Versus Nickel Alloys, *Chem. Eng.*, July 2022, pp. 31–36.

Extending the Life of Fluid System Components

With proper design, installation, monitoring and maintenance, chemical plant operators can increase the lifecycle of fluid systems — and the bottom line

Brian Aplin
Swagelok Co.

IN BRIEF

- FOCUS ON SYSTEM DESIGN FIRST
- CONSIDER ALL OPERATING CONDITIONS
- TRAIN FOR PROPER INSTALLATION
- PERFORM PREVENTATIVE MAINTENANCE
- STORE PARTS PROPERLY
- LEARN AS YOU REPLACE

Replacing a fluid system component costs more than just the price of the part itself. It also includes paying the procurement engineer, as well as the cost for installation and maintenance. But the largest expense incurred is when a plant must shut down a section of its critical infrastructure while the broken component is replaced. This delay results in lost productivity during downtime and can affect a plant's profitability.

Extending the life of fluid-system components is one way to reduce these replacement costs. The longer a component lasts, the longer a plant can avoid downtime and other related expenses. Fortunately, there are some proven ways to improve component lifecycles, lower maintenance costs and even maximize plant safety in the process.

Focus on system design first

One of the most crucial elements that often gets overlooked is how the design of a fluid system can affect the ways that components wear. For example, pressure and temperature fluctuations, waterhammer, vibration and contamination can all have a significant impact on how well a system functions and how components age. Using sound design principles is essential to limit these stressors to improve long-term performance.

Simplified designs are preferred. For example, designing a fluid system with fewer components and fittings means fewer opportunities for leaks, which can prove dangerous to operators and may be costly to repair. In addition, this simpler system design reduces the possibility of potentially costly and dangerous fugitive-emission pollution. For example, a traditional nonwelded pipe assembly contains multiple direction changes and requires numerous elbows and connection points. A modern piping system with bendable tubing can reduce the number of fitting connections to as few as four points — at the mechanical seal and the seal-support system (Figure 1). Nearly all the connections can be welded, including swept bends, which greatly reduces the number of leak points. For tips on when and how to use bendable tubing runs, see the sidebar on page 27.

As designs are simplified, it is important to that ensure all the components meet the operating parameters, including tempera-

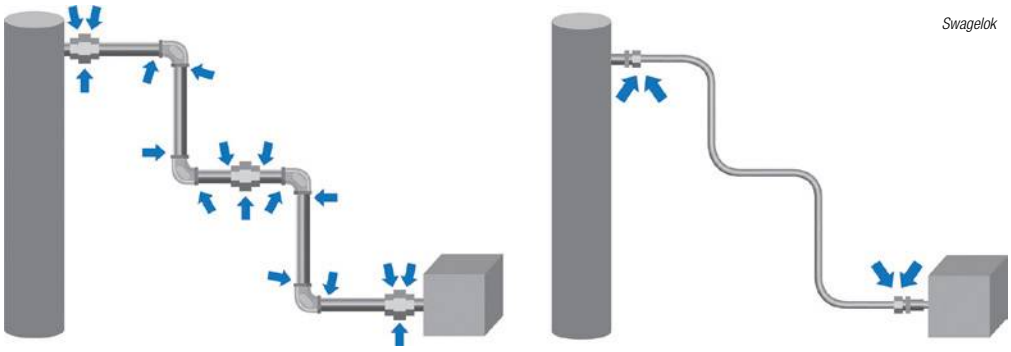


FIGURE 1. A simplified, multidirectional fluid system using bendable tubing (right) can greatly reduce the number of connection points — and therefore leak points — compared to a system featuring a nonwelded pipe assembly (left). The bendable tubing run reduces the nonwelded pipe assembly's 17 potential connection leak points down to just 4

FIGURE 2. Like pitting corrosion, crevice corrosion occurs when the protective oxide film on a component is broken down or damaged. Crevice corrosion (shown) differentiates itself from pitting corrosion by occurring in crevices rather than on exposed metal surfaces

ture and pressure, as designated by the manufacturer. With the components operating within these specified limits, the system will function at peak performance for a longer duration. No process change should go unexamined. For example, increasing the frequency of hose steam-cleaning could create additional heat exposure to the components and could reduce the usable life of the hose from five years to just one.

Consider all operating conditions

It is important to consider fluid systems holistically when deciding which components to specify. If the components throughout the system are chosen intentionally to work together, it is less likely that a surprise leak or failure will occur because incompatible components were used further downstream. Below are some important conditions to consider:

- Normal operating temperatures and pressures
- Maximum operating temperatures and pressures
- Ambient temperatures and conditions, including external exposure
- Process fluid and external media exposure
- Vibration potential
- Tubing and other supports
- Cleaning protocols

Taking process-fluid compatibility into account is often something that plant operators overlook. The components that encounter the process fluid, including O-rings and packing, should be specified with these interactions in mind. Using incompatible components could cause them to fail earlier than expected. Also, be sure to consider external conditions like high-chloride (saltwater) environments, which will accelerate the corrosion of some alloys, including 316 stainless steel. These conditions may require specific material choices, including jacketed tubing and special clamping or tubing-support options.

Additionally, components should be chosen to prevent issues like crevice corrosion (Figure 2), which occurs when the protective oxide film on a component is broken down or removed. In most fluid systems, crevices are formed between tubing and tube supports or clamps, between adjacent tubing runs, and under dirt and deposits that naturally accumulate on the surfaces of components. Though it is nearly impossible to avoid them completely, these issues pose particular danger to stainless-steel integrity, so choosing the right components to avoid this problem is essential to extending the life of the fluid system.

Train for proper installation

Once the system is designed properly with compatible components specified, the next potentially problematic area is the installation of the system. No matter how well the system works on paper, improper installation can undo all the hard work put in at the beginning.

When a system is improperly installed, it becomes even more likely that it will

prematurely fail. For example, if technicians are not trained on how to bend tubing properly, the system may experience side-load stresses that cause cracks and leaks. To maximize the benefits tube bending offers, it is important to understand how to identify where tube bends are most beneficial.

Directional changes using tubing can be accomplished by bends or by connecting separate lengths of tubing with high-quality tube fittings. Bends are applicable for many directional changes, but the choice between a bend or a fitting largely depends on the situation. Simple 90-deg directional changes (Figure 3) can often be most effectively accomplished with bends. Bending could also be beneficial in confined areas where several lengths of tube must stack in close proximity to each other.

Tubing requires adequate support to withstand the stresses of vibrations, which can otherwise lead to cracks and connection leakage. In addition, internal seals in valves might age unevenly if improperly installed. It is important to make sure tubing is installed correctly before the system is put into operation, including doing a proper gap inspection with a properly calibrated gap inspection tool. This can also be done during regular inspections and should be performed by external service engineers (Figure 4). These inspections could be performed virtually if required.

The most effective way to ensure that your fluid system components are properly installed is to train the installers extensively. Small details can have significant effects on how long the system will perform at its peak. Working with a supplier that can offer technicians the training they need will help mitigate installation issues and significantly enhance safety through proper installation.

Perform preventative maintenance

Though many fluid-system components will operate well without significant maintenance, that is not the case for all of them. In fact, regulators, valves and hoses should be inspected regularly and adjusted as necessary to ensure they reach their full lifecycle potential. The cost of performing regular maintenance is often less than that of replacing a component once it fails.

For example, it is important to regularly replace the packing in utility valves to reduce internal leaks across the seat.

THREE ESSENTIAL CONSIDERATIONS WHEN BENDING A TUBE

Though tube bending offers many benefits, it only makes sense if the bends are made in the proper places. Furthermore, bends are only effective if they are done in a high-quality manner. Here are some things to consider when determining whether tube bending makes sense.

Determine whether tubing will be advantageous over pipe. Tubing provides benefits over traditional pipe in situations in which labor and time are at premiums. In a particularly complex system application, pipes add additional fitting connections that may become potential leak points, even when assembled by a skilled technician. When tubing is substituted for pipe, directional changes can be accomplished with a bend rather than a fitting. In addition, tubing bends create far less turbulence in the system media than a pipe elbow. Finally, tubing is less heavy than pipe, which means it will not need as many supplementary supports.

Decide how you will perform your directional changes. In most tubing applications, directional changes will either be the result of bends or by connecting different tubing with high-quality fittings. Though bending may not work in every situation, tube bending is often the most cost-effective option to achieve leak-free directional changes. Specifically, 90-deg directional changes are candidates for using a tubing bend instead of a pipe connection. In systems in which tight spaces restrict how any lengths of tube and fittings can stack near each other, bending may make the most sense.

Make sure you have the right skills to perform tube bending. Tube bending is as much an art as it is a skill, requiring technicians to think in three dimensions to turn designs on paper into physical systems. Operators must also know how to use a tube bender and other equipment to complete accurate, quality bends. The two most common pieces of equipment for bending tubing are a hand tube bender (photo) and a benchtop tube bender.

A manual tube bender helps installers accurately and efficiently make bends in tubing at any angle

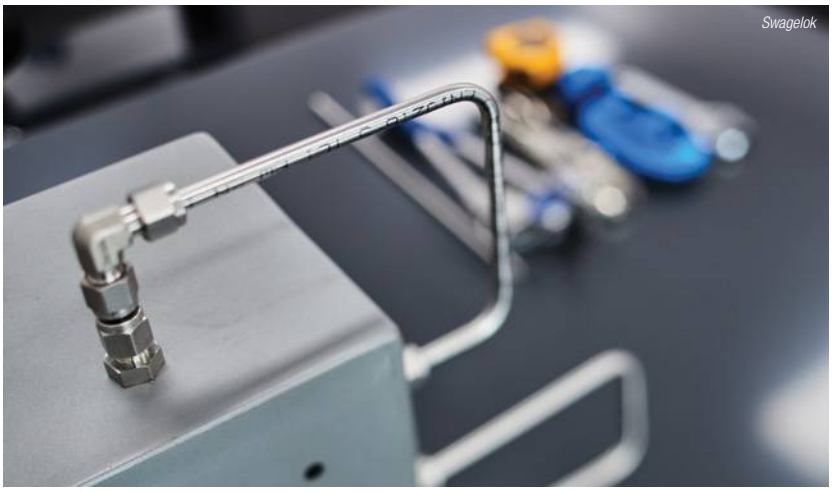


FIGURE 3. Bending tubing is often the best practice for making simple 90-deg directional changes

FIGURE 4. Tubing must be installed correctly before the system is put into operation. That includes doing proper gap inspections at every connection point

If the utility valve swings open, the fix can be as simple as opening the valve body, removing the old packing, and replacing it with new packing (Figure 5). This simple and effective repair saves significant time and money over removing and reinstalling or replacing the entire valve.

By keeping extensive records of the preventive maintenance performed on the system, it is possible to identify whether specific components are failing prematurely. If such a situation arises, operators can analyze the component and determine what should be changed, including replacing the existing component with one better suited to the application. Such analysis will allow the fluid systems at the facility to last longer and cost less over time. If the capabilities to perform such evaluations do not exist within the facility, it may be prudent to engage with a supplier that can provide those inspection services for you.

Store parts properly

It is important to keep a replacement inventory of specific system-critical components. However, you must be careful how you store these components. In the case of hoses, improper storage can lead to damage. You should never stack hoses. Instead, hoses should be hung to ensure they are not bending more than the manufacturer's published minimum bend radius. In addition, protect hoses from ultraviolet (UV) light, since some hose materials degrade from UV exposure. Finally, cap both ends of the stored hose to prevent contamination.

In the case of other fluid-system components, avoid mixing spare parts from different manufacturers in the same box or bin. Spare parts, such as ferrules, O-rings and valve packings, need to be separated and stored by manufacturer. It is also important that each spare part is clearly marked for its corresponding component. These parts are not interchangeable — even if they appear the same to the naked eye. Intermixing or interchanging parts from different manufacturers may lead to leaks, corrosion, or product failure. The new S-716 specification requirements for smallbore tubing and fittings from the International Association of Oil & Gas Producers (IOGP; London; www.iogp.org) also prohibit the intermixing of fittings from different manufacturers and instead mandate the use of a single tube-fitting brand for each project.

Combining components from different manufacturers often leads to poor performance, even when manufacturers create components out of the same or similar materials, small differences in composition can occur (Figure 6). This is why using components from different manufacturers can lead to unpredictable performance, including potential leaks and other safety-related problems during operation.

Learn as you replace

Though replacing fluid system components is part of running a successful plant, plant owners can save money over the long term by extending component life. That can be accomplished through proper system design, component selection, installation, maintenance and storage. When operators must replace worn-out or damaged components before their anticipated lifespan is over, it is critical to understand why the component failed. Evaluating the cause of

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FIGURE 5. Utility valves that swing open make packing replacements simple, enabling plants to quickly stop internal leaks across valve seats

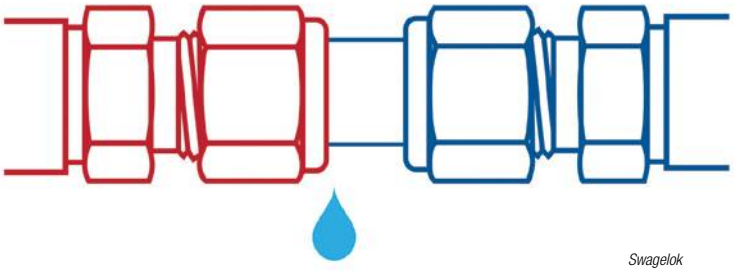

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FIGURE 6. Plant operators should avoid combining components from different manufacturers, as differences in tolerances between dissimilar components can lead to leaks and other potentially related safety problems

the failure may uncover a need for a different component — or even a different supplier. If a component failed because of pressure, temperature or material incompatibilities, it may be possible to find an alternative that will accommodate the process requirements. If the failure occurs because of a system-related issue, such as vibration, contamination, or waterhammer, operators should seek to correct the problem in the system and increase component life — and the bottom line. ■

Edited by Mary Page Bailey

Author

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For details visit adlinks.chemengonline.com/84644-12

Design for Safety: Tips for Proactive Risk Reduction

Thoughtful design can help reduce safety risks at process plant sites by proactively eliminating possible hazards and modifying personnel behaviors

Alan McCurdy
Independent consultant

IN BRIEF

- FOCUS ON UPFRONT DESIGN
- PROCESS AND PLANT DESIGN
- SAFE OPERATION AND MAINTENANCE

Safety is an important value in any organization, but is particularly important in the chemical process industries (CPI) when the design, construction, operation and maintenance of manufacturing facilities is concerned. No company or organization wants to have personnel injured, or to cause damages, and no entity wants to find itself in a situation where lawsuits are filed against it.

The design profession has an important role in ensuring safety because many risks can be "engineered" to be eliminated or reduced. The designer's knowledge, expertise and values can be leveraged to ensure that a facility can be safely constructed, operated and maintained. While personal protective equipment (PPE) is of critical importance to preventing and minimizing injuries, worker behavior can be just as important a factor in whether or not injuries occur, and modifying worker behaviors through design decisions can be a very effective way to prevent and minimize injury.

For design professionals, a central safety concept is striving to be proactive. Spending resources to prevent injuries is far more cost-effective than paying for the physical and emotional pain, the lost time and medical care from an injury after it occurs. Designing with proactive safety principles in mind can produce a facility or process with fewer hazards and lower risk. And a design that eliminates, reduces or mitigates hazards and risks upfront is an inherently safer design. This article provides a set of tips and best practices to consider in designing plants and process units that proactively increase safety and reduce risk. These are only some of the items to be considered for a safe design. Specific applications will likely require additional considerations.

Process and plant design

Design professionals should consider providing input into the construction planning, checkout and commissioning planning, as it pertains to safety, as well as into operations and maintenance procedures. The following recommendations are designed to help start off a project with a safe design foundation.

Match design basis to service. A smart beginning point is to develop a design basis that is consistent with the service. This includes the following items:

- The basis should include minimum, normal and maximum flowrates, temperatures, and pressures for the process. Note if these conditions cycle frequently and if the process is continuous or batch. Determine the design capacity, annual operating hours, and seasonal variation
- Use appropriate design standards and materials of construction for the materials, process conditions, and equipment. Consider the materials' properties: flammability, corrosivity, reactivity and health hazards in designs and specifications
- Consider a "requirements exchange" and a risk analysis early in the design process. These documents can be updated as the design progresses. A requirements exchange refers to a meeting (or series of meetings), where the client (including operations and maintenance staff) state their needs for the project. This could include requirements on process performance, the need for specific operations (for example, an ability to put certain control loops in manual control during startup or shutdown), or maintenance requirements (such as a backup for certain equipment, access to equipment for making adjustments, or additional valves to

FIGURE 1. Safe access to equipment, such as the pump with shaft guard shown here, reduces risk during maintenance activities

allow for equipment removal without extensive draining)

- Develop P&IDs (piping and instrumentation diagrams) or PFDs (process flow diagrams) to describe the process for design requirements. P&IDs and PFDs are important for correct operations and maintenance
- Develop electrical area classification (also known as hazardous area classification; HAC) layouts that include routine, intermittent or emergency venting of hazardous or flammable materials. HAC layouts provide the electrical installation requirements for equipment, devices, conduits and junction boxes
- Work toward developing a design that can be started up or shut down safely. Consider backup power and uninterruptable power supplies to prevent loss of control or emergency shutdowns
- Develop the requirements for field analytical equipment. This includes proper sampling location, instrument location and venting. Factor in the length of the sampling line to avoid lag time in the analysis. Do not forget to consider gas-cylinder storage and access
- Design adequate pipe and vessel pressure reliefs (from liquid/vapor expansion from internal temperature and sun exposure).
- Design adequate pipe and equipment supports, considering pipe and vessel movement from thermal expansion and equipment vibration
- Design foundations and structures considering the full weight of vessels with contents, platform loading, wind and snow loads, earthquake, seasonal weather conditions and soil-bearing capacity
- If appropriate consider fire protection systems, and protect structural steel from fire impingement with applied fire protection

Safe operation and maintenance

When the plant or process eventually begins operation, personnel will need to move in and around the process equipment, so it is desirable for designers to think about how operators and maintenance personnel can safely access equipment and monitoring and control devices (Figure 1). It is more cost effective to consider and plan for operations and maintenance during the design phase than to make changes for safer maintenance and operation after the design and layout are completed. This includes the following considerations:

- Consider access to valves, instruments and equipment, including clearance for swing areas for cabinets and doors. A design that allows access will minimize the number of pre-startup punch list items. For example, the following guidance should be considered: maintain a minimum clearance of three feet of workspace (increase clearance if equipment is needed for work); ground-level access is preferred over access at elevation; minimize "head knockers" by routing elevated pipe or conduits higher than head space or providing "walkover" platforms; provide for adequate platforms, while taking into account the work requirements; and stairs are generally safer than ladders (Figure 2)
- Provide guidance for equipment, vessel, pipe, valve and cabinet labeling, including flow direction for pipes. Permanent tags or labels are better than marker or paint-stick labeling
- Design adequate lighting and power sources for operations and maintenance, so that dark areas are minimized and the need for extension cords is avoided
- Consider redundancy in components, particularly for critical items. An in-line spare will allow a planned repair, instead of an unplanned shutdown. The storage locations for spare parts and equipment should be considered also
- Ensure adequate isolation of equipment and instrumentation. Use double block valves and bleeds (to vent). Also, design a safe path for the vented or drained materials.
- Consider the lifting and space requirement for equipment removal (pumps, valves, filters). If appropriate, design for davits or overhead rails
- Consider the personal and vehicle traffic flow and space equipment and facilities accordingly. Pave paths for personnel and vehicles. Consider parking requirements for operations and maintenance
- Provide adequate egress (two ways in and out) and consider the potential hazards, so an egress path will not be blocked by a hazard
- Evaluate and minimize noise. Size equipment and pipelines to reduce equipment rotational speed or velocities, and use insulation and design for noise abatement

FIGURE 2. When platforms, such as the one shown here, are required, it is safer to use stairs over ladders

Building and site considerations. Site layout can also have an impact on safety and risk reduction. Here are a set of considerations related to site layout that can help reduce safety risks:

- Minimize the potential inventory of raw materials, intermediates and products that are required to be stored on site at a given time. In addition to quantity, try to minimize the energy required during storage, including for temperature and pressure
- Consider the appropriate spacing of equipment, buildings and setbacks from property lines at the site
- Include lighting protection, wind and snow, and earthquake design requirements
- Consider physical site-security requirements (including fencing, access control, security cameras)
- Design closed-loop fill/vapor systems as feasible. Closed-loop filling systems provide a vapor return line from the vessel being filled back to the vessel that is being emptied (Figure 3). The objective is to prevent vapor from venting to the atmosphere. This setup has both safety and environmental benefits
- Enclose or winterize equipment
- Evaluate rain and storm-water runoff drainage
- Consider the appropriate containment for liquid vessels. This includes the size for full volume and rain accumulation. Evaluate rainwater accumulation and means to drain, either with sumps or drains. Designers should also take into account how to access the contained equipment

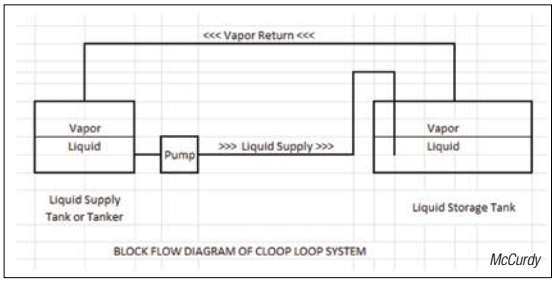

FIGURE 3. A closed-loop filling system, like the one shown in the diagram, provides a vapor return line from the vessel being filled to the vessel being emptied

Construction planning. Produce a design that allows the planning needed for a safe installation on a realistic schedule. Effective and thorough construction planning will reduce the need to rush work, work extra hours or take shortcuts with the construction procedures. The following are some specific considerations related to construction planning:

- Produce clear construction drawings and conduct interdisciplinary reviews to minimize clashes (for example, foundation misalignment with pipe layout, or conduit runs that hit pipe runs)
- Produce a design that allows pre-fabrication where applicable, so work can be done under controlled conditions
- Provide input into a daily risk analysis or job safety analysis (JSA) during construction activities
- Before performing piping or electrical tie-ins, consult with the owner's personnel so the appropriate isolation and de-energizing tasks are performed. Use equipment and valve lock-out procedures that include the appropriate communications and controls
- Minimize the complexity of lifted loads, both in weight as well as lifting equipment or materials in close proximity to hazards (including electrical power lines, existing process equipment and offsite facilities)
- When several crews are working on site at the same time, consider the risks of "simultaneous operations," so crews stay out of each other's work areas

Commissioning. The engineering professional should participate in pre-start-up walk-arounds with construction, design, operations and maintenance team members with the following objectives:

- Evaluate trip and pinch points, head knockers, valves that can be brushed open, and so on
- Do not forget bollards and other devices to protect piping and equipment from impact, both from internal or external traffic
- Develop a punch list and prioritize the items as "before" or "after" startup. These are items that were missed in design or construction, such as vents, or drains, equipment guards, steps, handrails, and labeling. Some items might be discretionary if not required for the project to be safe, meet standards or perform as designed.

For control rooms. Control-room design can also help reduce potential risks and increase safety.

- Consider automation with pro-

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cess information available in a control room or remote site. Remote automation reduces the need to operate equipment outside

- Consider control-panel heights relative to the ceiling heights. Conduits will generally be run either from overhead (or under the floor). In each case, adequate space for construction and maintenance is required
- Consider the control room layout and allow space for workstations, enclose door swings and wall penetrations
- Size the heating, ventilation and air conditioning (HVAC) systems of the facility to include control-system heat load
- Design for sufficient power recept-acles to minimize the use of extension cords

PPE and job safety

The use of PPE is now a minimum standard. Depending upon the work environment, the standard issue hard hat, safety glasses and steel-toed boots has expanded to include work gloves, goggles and facemasks, hearing protection, fire-resistant clothing and a host of atmospheric monitors.

Job-safety analysis. As design professionals gain experience, techniques for proactively eliminating hazards and reducing personnel risks through design decisions become more instinctive and intuitive. However, a systematic and comprehensive approach to assessing risks can help identify risks that could potentially result in unplanned incidents and potentially negative health consequences. A JSA can identify potential risks to personnel, as well as potential safeguards to eliminate or mitigate them. A comprehensive JSA might address the following:

- "Line of fire" injuries from tools, equipment, vehicles, lifted loads and so on
- "Fall" injuries resulting from slips, trips and falls from elevated-height positions
- Thermal injuries from contact with hot surfaces or flames
- Hazardous-materials exposure (via direct contact, inhalation or ingestion)

Hazard and risk assessments

Hazard and risk assessments, both within and outside the facility can be an important tool in increasing safety through design. Hazard and risk assessments are important early in the design progression, so the requirements that affect safety can be included early on, and design changes would not require great expense. Guidance would include the following recommendations:

- Design enough instrumentation, valves and check valves to control and isolate the process
- Consider the locations of vents (both routine and emergency), and factor these locations into personnel areas and electrical classifications
- Include the appropriate winterization of plant assets
- Consider permitting requirements, both current ones and in those in the future

Based on the results of hazard and risk assessments, safety systems with redundant instrumentation should be chosen for critical systems. For critical controls, consider dual, redundant instruments that use different technologies or working principles. For pressure-relief systems, ensure that they are of adequate size or volume, and that they are redundant in nature.

For more on hazard assessments, see the "Facts at your Fingertips" column on hazard-identification methods (*Chem. Eng*., February 1, 2022, p. 28). ■

Edited by Scott Jenkins

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For details visit adlinks.chemengonline.com/84644-15

Safety Aspects in the Instrumentation of Process Plants

Safety is often underestimated when planning, operating and maintaining process-measuring equipment. Sensors with SIL certification, alone, do not make the process safe. It is important to avoid systematic errors during planning, installation and operation

Lothar Gellrich
Krohne Messtechnik GmbH

IN BRIEF

AVOID SELECTION AND INSTALLATION MISTAKES
SIMPLE HANDLING INCREASES SAFETY
SYSTEMATIC ERRORS
AUTOMATED TESTING
AUTOMATIC PARTIAL TEST
FINAL REMARKS

The correct installation of a temperature sensor can determine whether a plant is safe for employees and the environment. Typical examples are exothermic chemical processes in which peroxides, nitrates or monomers react and control of the cooling capacity with reliable temperature measurements is vital — and sometimes control within narrow temperature limits is needed. The relationship between reaction rate and temperature follows the rule of the Dutch chemist Jacobus van 't Hoff. According to this rule, the rate of a reaction doubles when the temperature is increased by 10K. Accelerating self-heating can therefore lead to a thermal reaction (runaway reaction).

Decisive for the measurement task here is not only the accuracy and reliability of the sensors used. Human error in the planning of the metering point, the selection and installation of the sensor and its operation can lead to systematic errors. For example, insulating adhesions on sensors can cause values to be displayed that are too low. If a temperature measuring insert is not inserted far enough into the thermowell, the measured values are usually too low. In practice, such systematic errors are the most common reason for safety problems when handling process-measuring equipment.

What applies to temperature measurement is also valid for other parameters (Figure 1), such as flow and level. Here, systematic errors can lead to tanks being overfilled or mixing ratios not being correct during production, resulting in low-quality batches.

Typical questions in flow measurement are, for example: Are the inlet and outlet distances adhered to? What must be observed after a T-pipe? Can partially filled pipes or cavitation occur after valves or with pumps? And if clamp-on devices are used, are they correctly attached/strapped to the pipeline?

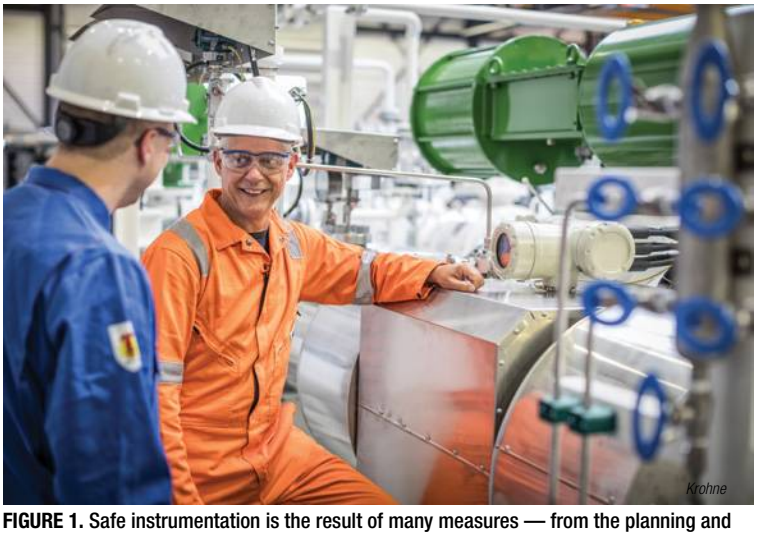

FIGURE 1. Safe instrumentation is the result of many measures — from the planning and implementation of the measuring point to the avoidance of systematic errors during operation and instrument testing

Avoid selection and installation mistakes

To avoid mistakes during installation, one can refer to video instructions [*1*]. These short explanatory films cover the complete lifecycle: from unpacking the devices to mechanical and electrical installation to commissioning and verification.

But even before installation, there are opportunities for error: Was the right measuring device selected in the first place? Are the measuring principle, range and material suitable for the application? Are pressure shocks or corrosion to be expected? What about secondary protection in the event that medium enters the instrument housing after a defect at the process connection? And finally, the question of whether the measuring device is installed correctly must be asked.

If, for example, a temperature sensor has to be removed from the plant for calibration, this involves a comparatively large amount of work: the plant has to be shut

down or at least the line in which the sensor is installed has to be bypassed. Nevertheless, the risk of leakage and contact of maintenance personnel with hazardous media remains. As support, an online webinar that points out mistakes to avoid when planning, operating and maintaining temperature sensors, is available [2].

Simple handling increases safety

An alternative to classic offsite calibration is in-situ calibration, for which special protective tubes for the sensor elements are available. These have two openings so that the calibration standard can be inserted into the same protection tube when installed. In this way, the calibration signal and temperature signal can also be compared in the installed state. This not only makes the calibration process simpler and safer, but also reduces the effort required. In practice, this leads to more frequent calibrations.

The importance of a safe measured value with regard to plant safety has already been mentioned. In order to ensure the safety of pressure measurements, elaborate 3D linearization can be used during production. With this approach, the devices for pressure and differential pressure measurement are linearized over the entire measuring range, not only for one temperature and one static pressure value, but for every theoretically conceivable constellation. This ensures that the transmitter provides the correct measured values for every possible process condition.

Systematic errors

Systematic errors can make safety integrity level (SIL) tests pointless. However, systematic errors not only affect control loops, but also occur in safety loops. Although failure probabilities are calculated for these as part of the SIL calculation and tests are carried out regularly, here, it is mostly the systematic (and usually human) errors that lead to failure.

The reason for this is illustrated by the example of an overfill protection system on a tank in which a hazardous liquid is stored. This system must be subjected to a proof test at regular intervals. How often this has to be done follows from the probability of failure on demand (PFD) calculation when designing the safety loop. PFD stands for dangerous failure probability in case of demand. How informative the test is, is in turn verified by calculation. The PTC value (proof test coverage) indicates how high the proportion of possible faults is that are detected during a proof test. If the sensor is removed and put through its paces, a PTC of 97 to 99% can usually be achieved. However, the effort required for this full test is high.

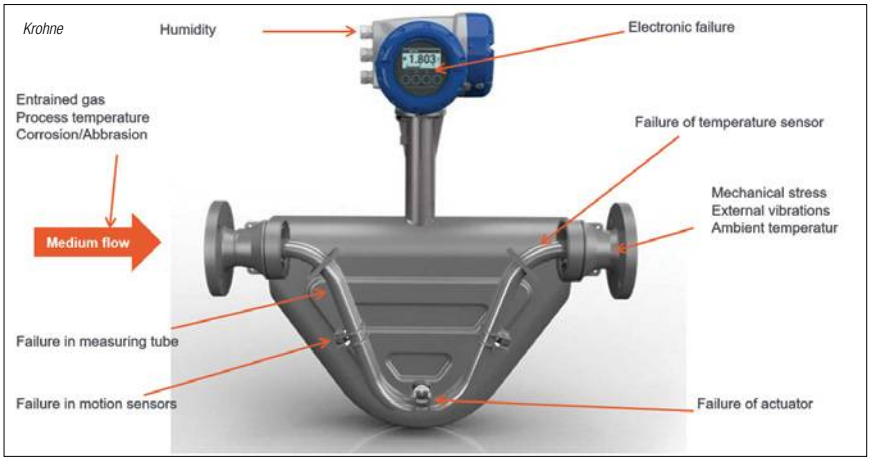

FIGURE 2. Possible sources of error in Coriolis flow measurement found via device diagnostics and partial proof tests

For this reason, the partial-stroke test method (partial-proof test) has been used for positioners for years. Because the test does not cover all possible errors, a PTC of 99% is not achieved, but the partial-stroke test can still be used to exclude many possible errors.

Automated testing

What applies to actuators can of course also be applied to operational measuring devices in safety functions (Figure 2). Many field devices already have extensive self-diagnostic functions and perform automatic tests — this usually allows for 95% of all possible errors to be detected. However, it gets difficult for the remaining 5%. To eliminate these in tests, the user usually has to go on site, disconnect the device from the safety loop, put it into a simulation mode and compare current signals simulated by the device with their setpoint.

Time and again, devices fail to switch from simulation mode back to SIL operating mode during such tests. In addition, there are wiring errors following the test. And so the question arises as to whether the manual partial test does not actually increase the risk of failure. After all, the probability of the operator making a mistake during testing is far greater than that of a device failing due to a device error.

To avoid human errors, vendors have developed ways to automate the partial proof test. To do this, the manufacturers use a special feature of their device or the controller. For example, the SSPS HIMax can activate the HART channel, which is

FIGURE 3. Safe measurement also includes safe communication with the measuring devices

normally switched off in SIL mode. The safety controller then takes the field device out of SIL mode via the HART protocol and temporarily switches it to simulation mode, comparing the setpoint and actual value of the 4–20-mA signal. Finally, the device is automatically switched back to SIL mode, restarted and the HART channel is deactivated again. The results of the test are documented.

Automatic partial test

However, this is only possible with devices that allow HART commands in SIL mode. To prevent HART communication from being compromised during the automatic partial test, the SSPS saves the device configuration and detects deviations. This eliminates a major criticism of HART communication with SIL devices: in contrast to the classic setup, where the HART signal runs via a multiplexer (for example, connected to an asset management system), communication only runs between the SSPS and the field device. While hacker attacks cannot be ruled out via asset management stations, this risk is virtually eliminated with safety controllers.

Secure data transmission and storage are also important. Secure Bluetooth connections for communication with devices are now available (Figure 3).

These measures are also part of the "Secure Instrumentation" concept. In addition, for Coriolis instruments, for example, there is a housing concept that prevents medium from escaping through the transmitter housing even in the event of sensor damage.

Final remarks

Safety in the instrumentation of process plants has many facets and goes far beyond functional safety. Systematic errors represent a significant influencing variable in the planning, operation and maintenance of measuring points, and they can be avoided through training, video instructions as well as automated test procedures. ■

Edited by Gerald Ondrey

References

1. https://krohne.com/mydevice-de/icv-videos.
2. https://academy-online.krohne.com/de.

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Filtech 2023

Filtech 2023, which takes place on February 14–16 at the Cologne, Germany fairgrounds, will feature more than 440 exhibitors and a major international conference. There are also two short courses being offered on February 13: A one-day course on solid-liquid separation, and a one-day course on fine-dust separation. Among the innovations being exhibited at the show are those dealing with air filtration, fine dust values and gases that affect the climate, as well as germs that are harmful to health and other impacts. Solids separation and solid-liquid separation are also being highlighted, with new developments striving for maximum efficiency and higher product qualities. The following are a few examples of products being exhibited at Filtech 2023.

A membrane module for wastewater-treatment plants

The BIO-CEL M+ membrane module (photo) is optimized for use in mobile and medium-sized wastewater-treatment plants (<1,000 m³/d). It fits perfectly into a High Cube container (for decentralized and mobile wastewater-treatment plants), which allows the construction of extremely compact decentralized wastewater-treatment plants. The module is submerged in aerobic bioreactors where it filters bacteria and solids. This function makes a wastewater-treatment plant more efficient, as the footprint of the plant is reduced by 50 to 60% compared to a conventional wastewater treatment plant, the company says. BIO-CEL M+200 can produce an average of 75 m³/d of filtrate and treat the wastewater of 480 PE (population equivalent). This corresponds to the wastewater of about 115 households. Hall 8, Stand C11 — *Mann+Hummel Water & Fluid Solutions GmbH, Wiesbaden, Germany*
www.mann-hummel.com

This air-treatment system uses anti-microbial filter elements

The pandemic highlighted the importance of effective ventilation systems, including for schools, offices, restaurants, theaters and exhibition centers. With its comprehensive portfolio of ventilation and air-conditioning systems, this company provides a tailored solution for each of these challenges. This company is a global leader in the development and manufacture of components, appliances and systems for indoor air conditioning and ventilation. The company uses antibacterial polyurethane systems from Rampf Polymer Solutions and the DR-CNC dispensing robot from RAMPF Production Systems to seal, cast and bond its air filters (see story below). It uses a RAKU PUR two-component adhesive to manufacture its new X-CUBE X2 series of air handling units (photo). The new air-handling unit (HVAC) X-CUBE X2 can be configured for virtually any application. Hall 7, Stand H12 — *TROX GmbH, Neukirchen-Vluyn, Germany*
www.trox.de

Material and machine from a single source

The DR-CNC dispensing robot (photo) is used to process this company's rigid foam system for sealing the filter elements. Features include highly adaptable X-Y-Z axis strokes and state-of-the-art control technology that combines the mixing and dispensing system perfectly with the maintenance-free CNC linear axes. The result is flawless interplay between the dispensing process and motion sequences. The bonding system that joins the individual components of the sandwich panels has a short curing time, exceptional mechanical strength and high temperature and chemical resistance. The company has collaborated with TROX (see story above) to develop high-performance polyurethane filtration systems that are tailored perfectly to the relevant application requirements. Hall 8, Stand E29 — *RAMPF GmbH & Co. KG, Grafenberg, Germany*
www.rampf-group.com

Metallic filter media in dynamic crossflow filtration

In contrast to classic crossflow filtration, in dynamic crossflow filtration with the BoCross filters (photo, p. 38), the typical tangential overflow of the filter surface is not generated by the geometric flow control in the apparatus, but by rotors. This principle offers

Mann+Hummel Water & Fluid Solutions

TROX

RAMPF

Bokela

Aquachem

Fraunhofer-Institut für Keramische Technologien und Systeme IKTS

Lenzing Filtration

decisive process advantages, because the physical conditions for the separation process are nearly ideal. The throughput is therefore up to 10 times higher than with classic crossflow filtration, the company says. Furthermore, it is also possible to process suspensions with high concentrations or viscosities, because there are no narrow spaces and gaps. In particular, the use of metallic filter media in dynamic crossflow filtration with the BoCross filters enables versatile and completely new process solutions. For tasks such as classifying, clarifying liquids and concentrating solids, these new processes offer powerful solutions where state-of-the-art technologies, such as wedge-wire screen, candle filters, backflush filters, vibration screens, centrifuges or membrane filters reach their limits. Hall 8, A45 — *Bokela GmbH, Karlsruhe, Germany*
www.bokela.com

Detect machine failures before they occur

Via remote access, owners of fully automatic filter presses (photo) from this company can now easily view their processes from anywhere and measure and evaluate their process data. The cloud-based solution, Roxia Malibu, is a combination of online process monitoring, maintenance, reporting and analysis tools with which production processes can be optimized and operational disruptions can be reduced. Roxia Malibu is not just an industrial internet of things (IIoT) portal, but also houses artificial intelligence in the background that optimizes the filtration cycle to the highest level. This company's experts help to optimize the entire filtration process to achieve the desired cake moisture and maximize filter capacity. They help pinpoint bottlenecks to avoid unplanned downtimes. Hall 8, Stand A38 — *Aquachem GmbH Separationstechnik, Senden, Germany*
en.aquachem.de

Membranes separate H_2 from CH_4, CO_2 from industrial gases

This institute has developed a technology based on carbon membranes that can be used to efficiently separate hydrogen and natural gas, thereby enabling both gases to be transported together through natural gas networks and subsequently separated from each other as needed at the destination. Compared to pressure-swing adsorption (PSA) or cryogenic separation processes, this variant is said to be cost-effective and resistant to harsh ambient conditions and natural gas byproducts, such as H_2S. The membranes can concentate 5 vol.% H_2 in the feed to significantly more than 90 vol.% H_2 in the permeate. Due to their excellent stability even at high temperatures, the carbon membranes are also suitable for the separation of CO_2 from industrial gases. During test runs at relevant CO_2 emitters (steel, lime and dolomite works, biogas plants), CO_2 concentrations of more than 97% could be achieved. This makes it possible to further utilize the separated CO_2 as a raw material for non-fossil fuels or chemicals, for example. Hall 7, Stand L36 — *Fraunhofer-Institut für Keramische Technologien und Systeme IKTS, Hermsdorf, Germany*
www.ikts.fraunhofer.de

Improved backwashing of filter candles

Last year, this company filed a patent for a new cake and precoat filter candle design. The target was to develop a support structure that is inexpensive to fabricate and that at the same time provides the lowest possible flow barrier, allowing for a backwash flow as high as possible throughout the total candle length. The CakeFil technology (photo) assures real process automation without interruption periods or any manual operation. The discharge functions either as slurry or, after an optional previous cake washing and drying step, as dry-to-the-touch discharge. Beside its precoat and cake-building technology, the company is also exhibiting its reliable backwash-filtering system for finest filtration of fluids for industry and for water treatment. The OptiFil and ViscoFil technologies ensure the highest process continuity at the lowest backwash quantities. Hall 7, Stand L12 — *Lenzing Filtration, Lenzing, Austria*
www.lenzing-filtration.com ■

Gerald Ondrey

Wireless Data Collection: Stop Chasing Reliability Data

A routes-by-exception reliability strategy helps improve safety and efficiency, while preserving competitive advantage in a changing marketplace

Asad Malik
Emerson

In recent years, maintenance and reliability experts have often talked about the massive wave of retirements leaving chemical plants, creating a shortage of expert personnel able to collect and analyze the data needed to run the plant at peak performance. They are not wrong. However, while a shortage of personnel and an increased focus on productivity have recently changed the way process manufacturers must operate, there has long been a push to collect data more efficiently. The solution — wireless data collection and analysis — has been available for many years. But now, a manufacturing landscape changed by the COVID-19 pandemic and a global marketplace has simply accelerated the need.

Today's wireless sensing devices use powerful software to turn reliability personnel into digital workers. These tools eliminate the need for maintenance and reliability personnel, and, in many cases, even operators, to spend precious time roaming the plant collecting data, entering it into a centralized system, and then sitting down to analyze it. Wireless technologies not only bring data directly to the personnel who need it, they are also affordable and easy to install, making it possible for plant personnel to monitor and make decisions about the health of any plant assets, no matter their level of experience.

Problem 1: Data chasing

Traditional maintenance strategies require two key resources — personnel and time — and many modern plants are short on both. Today's large specialty chemical plants often have many more assets than they have personnel to monitor and service them. In the largest plants, these assets are often significant in size and distant from one another.

Collecting asset-health data manually means sending personnel out into the field or plant floor with handheld analyzers to manually check each piece of equipment. This process is not only time-consuming; it also frequently puts personnel at risk. It is not unusual for the data-collection process to take six to eight hours or more for a large asset, and often requires personnel to scale tall equipment or extend a handheld analyzer into hard-to-reach places.

In many cases, the majority of data collected indicates that assets are generally healthy — which means time and resources may have been spent examining equipment that would have performed well without supervision. Moreover, when technicians return from collecting data, they must then enter those data into a centralized system, where the data can be used. Finally, someone — often that same worker — must analyze the data.

As a result of these and other hurdles to efficient and safe data collection, plants typically try to spread rounds out over as long a period of time as possible. It is not unusual for plants to space manual-maintenance rounds weeks or months apart. And when the plant's already limited personnel are unavailable, it is common for rounds to be postponed. But mechanical failures do not wait for observation. If a bearing checks out today, but begins developing a malfunction tomorrow, it could be months before maintenance staff identifies the problem. In the worst-case scenario, a failure causing unexpected downtime could result.

Solution: Data where needed

Instead of tying up essential plant personnel on the low-value task of walking around the plant collecting data, today's forward-thinking reliability teams are harnessing the power of wireless technology and software dashboards to bring critical plant data directly to them, on demand, wherever they may be. Today's wireless vibration sensors can help plant personnel quickly and easily determine the source of a problem via intuitive dashboards, eliminating the need to examine the asset locally and identify malfunctions.

FIGURE 1. Wireless edge devices, such as the one shown here, are easy to install right at the asset, and can send machinery-health data to personnel wherever they may be

Innovative reliability teams are installing small-form-factor wireless sensing and edge-analytics devices right at each asset (Figure 1), then connecting these devices to wireless networks, which transmit data to asset-management systems. These devices require no cabling, which both eliminates the high cost of installing sensors, and makes it far easier to gather critical data from remote equipment where running cables can be expensive, difficult, or both. Typically, plant personnel can install these devices to deliver detailed triaxial sensing data for most plant equipment.

By eliminating the need for personnel to perform manual rounds, reliability teams free them up for other essential plant tasks, helping the plant do more with fewer people. Personnel are not only safer, but also more mobile, as many wireless sensing devices can deliver data directly to software on a handheld device,

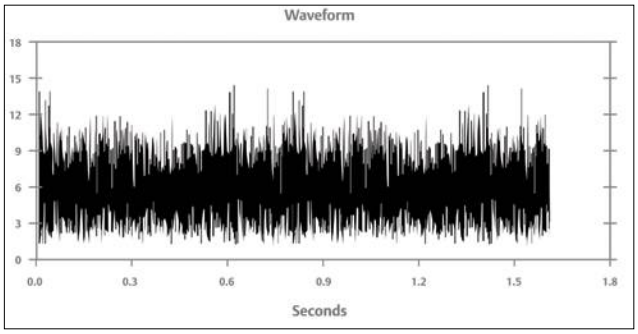

FIGURE 2. Reading waveform data, such as the spectrum shown here, can be a complex task for inexperienced personnel

such as a tablet or mobile phone. This untethers digital workers from manual rounds, and even from the control room.

Instead of collecting data every couple of weeks or months, wireless sensing technologies enable plants to collect critical data every few minutes or hours. Reliability teams can maintain constant vigilance over assets, regardless of their criticality, helping to eliminate unplanned outages and unexpected emissions for more reliable, sustainable operations.

Small sensors bring big results

For one large North American power producer, small wireless sensors installed on a cooling water pump avoided a big hassle.

The plant had moved from manual maintenance rounds to wireless vibration monitors, which delivered spectrum, waveform, and embedded analytics to maintenance personnel and operators in the control room. Shortly after installation of the wireless sensors, maintenance personnel were notified of a critical alert status regarding lubrication of a cooling-water pump motor.

The waveform data indicated there was a problem with impacting, and a lubrication display in the red zone showed the cooling-water pump likely had a dry motor bearing. Technicians greased the bearing and collected vibration data on demand, this time with the impacting eliminated and lubrication status in the green zone due to dramatically lower vibration levels.

By setting up their reliability equipment to deliver actionable information to the right people at the right time, the plant avoided a potentially costly equipment failure and extended downtime.

Problem 2: Upskilling personnel

One of the key metrics by which reliability teams judge their success is response time. When there is a problem in the plant, teams should be able to respond quickly and effectively — a task that was much easier ten or fifteen years ago, when plants often had a "deep bench" of expert personnel to identify, analyze and solve equipment issues.

Today, however, plants are running with far fewer personnel, and those people often have far less experience. Most vibration-related equipment problems will fall into one of a few common categories:

- Balance
- Alignment
- Looseness
- Blade pass
- Bearing
- Lubrication

However, identifying those problems from just raw spectrum and waveform data can be a complex undertaking (Figure 2).

A new technician typically needs two to three years of experience before he or she can analyze raw data and identify the root cause of a problem. Waveform data identifies the severity of a problem, but without an identified source, that information is difficult to use.

Severity and source are interlinked, and manually making that connection using spectrum and waveform data to identify the most common equipment problems will be difficult for new personnel. Waiting two to three years for them to gain these skills has the potential to result in significant downtime and loss.

Solution: Decision support

Instead of waiting for new technicians to come up to speed over several years, today's reliability teams are implementing decision support through edge-analytics software to more rapidly upskill and assist personnel. Many of today's wireless edge devices contain embedded prescriptive analytics tools, effectively building expert knowledge into the device.

Instead of spending hours evaluating and manually analyzing raw data, digital workers simply access the report provided by the software on the edge device. In the most advanced edge devices, these tools are intuitive enough to be used by a person with no analytics experience whatsoever. For example, equipment health can be identified by color — green, yellow or red, based on severity of defects — and the software can inherently identify the most common equipment faults (Figure 3).

Using the intuitive screens instantly displayed on their console or web device, personnel can address problems immediately (when possible), flag them for maintenance during a scheduled outage, or travel to the asset with a handheld analyzer to gather more information for deeper troubleshooting. Traveling to the machine with an analyzer is the exception, not the standard, ensuring the time spent manually investigating equipment only occurs on the small number of failing machines.

Routes-by-exception

One North American manufacturer was producing products that became very popular during the COVID-19 pandemic, forcing them to rapidly increase production. Upping production increased the potential for problems, and it also meant less room for error because any downtime caused by equipment outages would result in lost production of critical supplies.

An edge device with embedded analytics software detected and identified lubrication issues on six assets, enabling the maintenance team to intervene before failure. Moreover, it also triggered vibration alarms as supply fans began experiencing problems during production increases. Immediately following up on the vibration alarm not only helped the maintenance team iden-

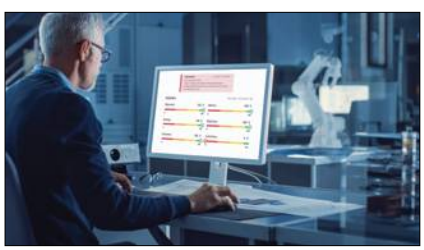

FIGURE 3. Analytics tools for machinery analysis, provide a simple and reliable indication of equipment health

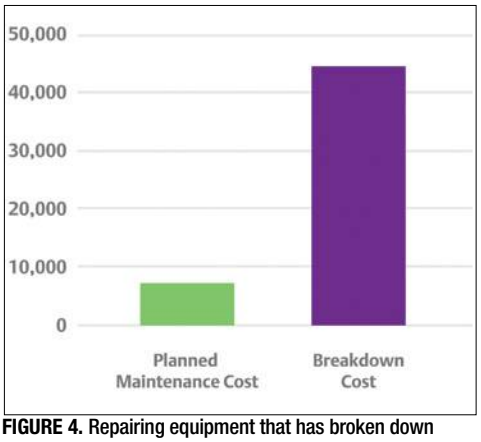

FIGURE 4. Repairing equipment that has broken down can cost 5–10 times more than performing planned maintenance before failure

tify clogged filters at the facility before they caused damage, but also prompted personnel to proactively clean and check filters in other facilities as their production ramped up as well.

Problem 3: Unplanned outages

Equipment breakdowns are very expensive. Estimates from the author's company suggest breakdowns generate five to ten times the repair cost of planned maintenance, and those estimates do not include the revenue lost to interrupted production (Figure 4).

Beyond financial cost, however, many organizations also experience opportunity loss when equipment breaks down. When an important machine is down, product is not manufactured, leaving a gap in market supply. These gaps are the opportunities competitors need to capture market share.

In the best scenarios, machines will not need repair until there is an opportune time to shut down the processes, but even planned outages are not without risk. Maintenance activities are time-consuming and subject to all manner of potential setbacks, including out-of-stock parts, malfunctioning tools, machines that are difficult to access or move, and more. If scheduled outages are not properly planned, they can easily run over time and budget, with costly consequences.

Solution: Preparing resources

To offset the risk of equipment breakdowns leading to outages, reliability teams are taking advantage of edge devices with embedded analytics software to unlock predictive maintenance information. When asset-health information is delivered in real time to the control room, or to the mobile devices of operators and technicians — in either case, using intuitive health scoring — reliability teams are aware of impending failures long before they become breakdowns. This type of warning is critical for properly scheduling maintenance activities during planned outage periods.

The most effective reliability teams, however, are using predictive maintenance via wireless sensing technologies to do more than just predict the time to failure. These teams are using all the digital tools at their disposal to prepare for planned outages that are as efficient as possible.

The analytical data provided by edge devices and sensing technologies helps teams plan their resources properly for maintenance windows. Before a machine stops running, teams can know what they need and have those items on site and ready to go. This can be as simple as having the right parts on hand, or as complex as ensuring a crane is in place and ready to get large parts into and out of a building.

Edge analytics

For one reliability and maintenance team that put an edge-analytics device on a forced-draft fan motor, embedded analytics software not only helped identify an issue and its severity, but also prepared them to perform repairs on schedule.

When their edge device identified a lubrication problem inside a sealed bearing, the team could not simply add grease while the machine ran. Knowing a true internal lubrication issue would likely mean fully replacing the motor, the team used handheld analyzers to collect raw data for a second opinion. When spectrum and waveform data from route-by-exception collection supported the dry-internal-bearing analysis, the maintenance team made the decision to replace the motor.

Knowing the replacement was a large job, and that the technicians would only have a short maintenance window, the reliability and maintenance teams had the replacement motor and all spare parts, the crane, and all necessary tools and staff ready the moment the machine was shut down during a scheduled outage. By ensuring that everything was ready before undertaking the project, the team likely saved ten to fifteen hours of maintenance time, and was able to complete the replacement well within the scheduled outage.

Making data work for you

Competing in today's global economy means making the most of every production moment. Savvy organizations know their reliability teams are key to ensuring that production is the best it can be, but they also know those teams cannot perform at a high level without the right tools.

Wireless sensing and edge analytics technologies are affordable and more powerful than they ever have been, providing reliability teams with the digital tools they need to transform the way they operate, so they can reduce downtime while increasing safety, availability, and productivity. Instead of chasing reliability data around the plant, the best teams bring the reliability data to the right people wherever they are. These teams use this information to make impactful decisions, upskill personnel, and get the most value from every moment spent in the plant. ■

Edited by Scott Jenkins

Acknowledgement

All figures courtesy of Emerson

Author

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Designing a Multi-Stage Thermal Oxidizer System

Thermal oxidizers can be used for the abatement of a wide range of air pollutants and volatile organic compounds. This article describes the custom design of a thermal oxidizer to treat three different waste streams from a biogas plant

Anu D. Vij
Ship & Shore Environmental, Inc.

A biogas company needed a treatment system for emissions abatement of volatile organic compounds (VOCs). The system would be installed downstream of a pyrolysis furnace and multiple condensers in order to thermally oxidize three waste streams high in sulfur and nitrogen concentration, while also limiting the formation of oxides of nitrogen (NOx). A custom proprietary system was designed, engineered and fabricated by Ship & Shore Environmental (S&SE; Signal Hill, Calif.; www.shipandshore.com) to meet this plant's unique specifications.

The system

The main distinguishing characteristic of thermal oxidizers is that they do not rely on direct ignition of the process gas for oxidation. Rather, they sustain the correct combustion conditions by maintaining an operating temperature sufficiently above the auto-ignition point by providing enough time for combustion and by the presence of excess oxygen to complete the oxidation reactions.

The multi-stage thermal oxidizer system designed by S&SE (Figure 1) needed to operate under vacuum in order to pull a vacuum on the pyrolysis reactor and provide the motive force for the flow of the produced gas from the pyrolizer (Stream 1) to the thermal oxidizer. Streams 2 and 3 are supplied to the thermal oxidizer through positive-displacement pumps. The induced draft/vacuum was designed to sufficiently pull all of Stream 1 into the thermal oxidizer to maintain a proper vacuum at the Stream 1 connection point. The plant's waste streams contain sufficient nitrogen content that if directly oxidized in a standard thermal oxidizer, an excessive amount of NOx would form. Thus, in the new thermal oxidizer unit, the streams are burned in a staged operation where the initial stage is a high-temperature reducing (oxygen-starved) atmosphere. The high temperature and more than 1-s residence time assure dissociation of organic compounds. Since combustion of the waste streams is exothermic, the process uses virtually no natural gas, except during startup, which greatly reduces costs. The exhaust gas from this initial stage contains an excess of combustible compounds, primarily carbon monoxide, and hydrogen. This reducing atmosphere provides proactive control of NOx, as bound nitrogen compounds are converted to diatomic nitrogen (molecular N_2) instead of NOx.

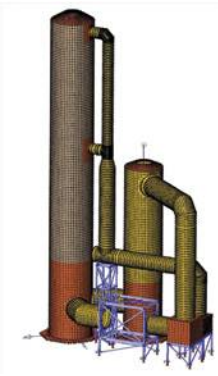

FIGURE 1. A customized thermal-oxidizer system was designed to handle the contents of three distinct waste streams from a biogas pyrolysis unit

There are typically two primary processes for the subsequent stages in a multi-stage thermal oxidizer. One process uses two additional stages (for a total of three stages). The initial stage is the reducing stage. A second reducing stage occurs in the thermal oxidizer (second chamber), which is still in a low-oxygen environment with a temperature of about 1,650°F to prevent excessive NOx formation. Following this stage, the fluegas enters the cool-down process. The cool-down process is split into two outlets, with one outlet going through the quench phase, while the second outlet is going through a heat exchanger. The second outlet can be used to increase the inlet temperatures (Streams 2 and 3), or to recover heat that can be used anywhere else in the plant.

Such a system, defined as a low-NOx thermal oxidizer, is not designed for 100% NOx destruction, but combining it with a selective catalytic reduction (SCR) system can eliminate the production of NOx. Limited space and potential excess production of NOx due to waste streams high in nitrogen provided unique challenges for the engineering team at the biogas plant.

S&SE designed the system vertically to fit into the limited space available at the site. One of the advantages of the vertical-system configuration and its down-fired burner is that any possible effect of ash or particles on the burner was eliminated. Simultaneously, the plant does not need to use any natural gas for combustion, which significantly saves on costs. Finally, the heat exchanger allows the plant to utilize a significant amount of heat elsewhere in the plant at no additional cost. ■

Edited by Mary Page Bailey

Author

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Economic Indicators

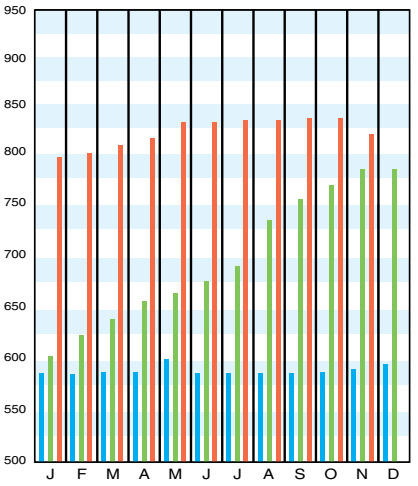
2020 2021 2022

Download the CEPCI two weeks sooner at www.chemengonline.com/pci

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957–59 = 100)	Nov. '22 Prelim.	Oct. '22 Final	Nov. '21 Final
CE Index	815.2	816.2	773.1
Equipment	1,033.8	1,034.4	973.8
Heat exchangers & tanks	862.7	865.7	825.7
Process machinery	1,041.7	1,040.4	976.7
Pipe, valves & fittings	1,461.2	1,462.3	1,402.1
Process instruments	555.3	549.6	569.3
Pumps & compressors	1,323.2	1,321.8	1,178.8
Electrical equipment	785.8	781.1	672.4
Structural supports & misc.	1,155.7	1,160.6	1,056.6
Construction labor	359.8	362.4	348.2
Buildings	802.5	807.8	796.3
Engineering & supervision	312.5	311.6	310.5

Annual Index:
2014 = 576.1
2015 = 556.8
2016 = 541.7
2017 = 567.5
2018 = 603.1
2019 = 607.5
2020 = 596.2
2021 = 708.8

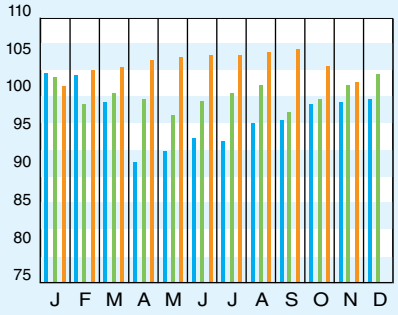


Starting in April 2007, several data series for labor and compressors were converted to accommodate series IDs discontinued by the U.S. Bureau of Labor Statistics (BLS). Starting in March 2018, the data series for chemical industry special machinery was replaced because the series was discontinued by BLS (see *Chem. Eng.*, April 2018, p. 76–77.)

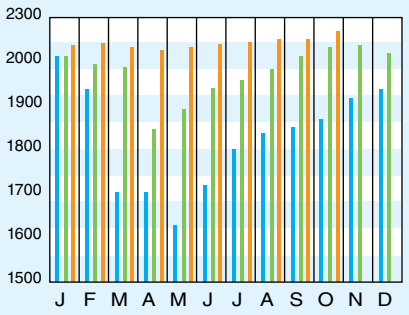
CURRENT BUSINESS INDICATORS

	LATEST	PREVIOUS	YEAR AGO
CPI output index (2017 = 100)	Nov. '22 = 100.2	Oct. '22 = 101.1	Sept.'22 = 101.1	Nov. '21 = 100.4
CPI value of output, $ billions	Oct. '22 = 2,219.7	Sept.'22 = 2,187.2	Aug. '22 = 2,174.5	Oct. '21 = 1,916.3
CPI operating rate, %	Nov. '22 = 80.8	Oct. '22 = 81.5	Sept.'22 = 81.6	Nov. '21 = 81.6
Producer prices, industrial chemicals (1982 = 100)	Nov. '22 = 345.8	Oct. '22 = 349.6	Sept.'22 = 352.5	Nov. '21 = 341.4
Industrial Production in Manufacturing (2017 =100)*	Nov. '22 = 101.6	Oct. '22 = 102.2	Sept.'22 = 102.0	Nov. '21 = 100.4
Hourly earnings index, chemical & allied products (1992 = 100)	Nov. '22 = 203.3	Oct. '22 = 203.0	Sept.'22 = 204.7	Nov. '21 = 193.3
Productivity index, chemicals & allied products (1992 = 100)	Nov. '22 = 92.6	Oct. '22 = 93.2	Sept.'22 = 92.0	Nov. '21 = 96.5

CPI OUTPUT INDEX (2017 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)

*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2012 to 2017
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the *CE* Plant Cost Index (CEPCI; top) for November 2022 (most recent available) fell slightly from previous month's value. The decline is the fifth consecutive monthly decrease, following a long string of increases between November 2020 and June 2022. For November 2022, the Equipment, Buildings and Construction Labor subindices all fell, offsetting a small increase in the Engineering & Supervision subindex. The current CEPCI value now sits at 5.4% higher than the corresponding value from November 2021. Meanwhile, the Current Business Indicators (middle) show decreases in the CPI output index and the CPI operating rate for November 2022.